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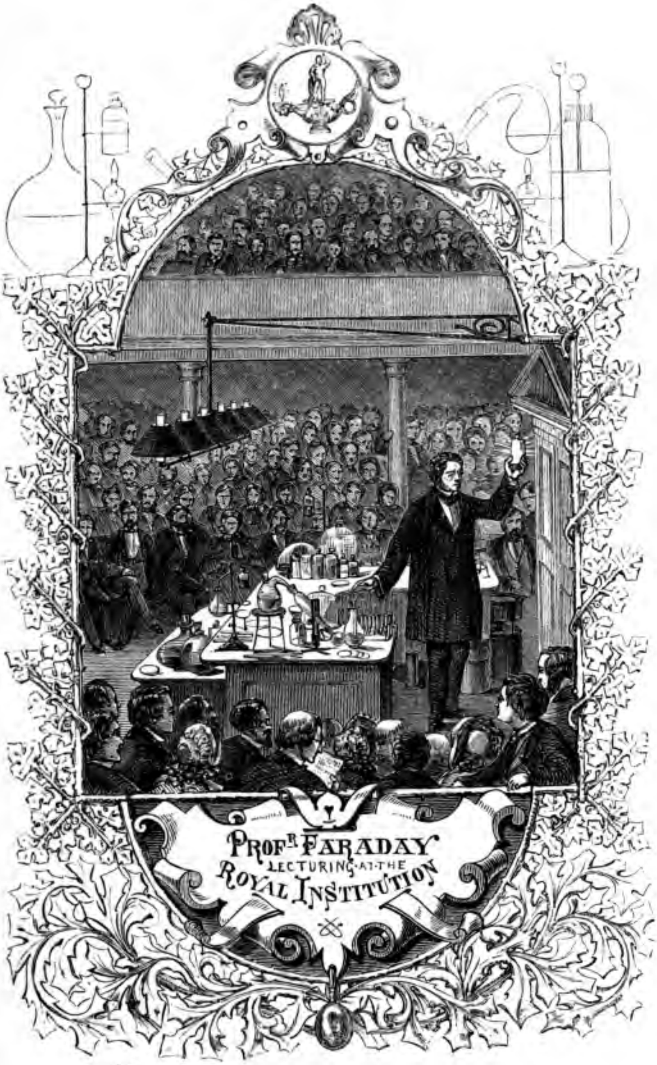
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MAGIC OF SCIENCE:

A MANUAL OF

EASY AND INSTRUCTIVE

SCIENTIFIC EXPERIMENTS.

BY

JAMES WYLDE,

FORMERLY LECTURER ON NATURAL PHILOSOPHY, ETC., AT THE
LONDON POLYTECHNIC INSTITUTION.

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INTRODUCTION.

In attempting to interest young people by means of scientific experiments, a serious difficulty has to be encountered from the idea generally entertained that the study of science is uninviting and difficult. The popular expositions of the subject have a tendency to confirm this impression; and from the array of apparatus on the lecture table, and the technical phraseology often employed, the impression is arrived at that science can only be pursued by those who make it their profession.

This feeling is much to be regretted, for it deters many from pursuing that which, after the first difficulties are overcome, is found to be the most fascinating of all the objects to which our intelligence can be directed. What, we would ask, can be more interesting than the inquiry into the causes of those changes which we are daily witnessing in nature, and which in many cases we can repeat on the small scale in our laboratories?

The question of expense is often urged as a reason for not pursuing science, and throughout the following pages we have endeavoured to remove the grounds of this objection. The whole of the experiments in our Chemical Section can be tried, with two exceptions, with apparatus costing about ten shillings; and the course has been so arranged as to include all the leading class illustrations generally shown at public lectures. We would here remark that experimenting at the lecture table and in the laboratory is a very different matter. At the former the lecturer generally makes a great display of apparatus, and has to make all his experiments on the large scale, so that all present may observe the effects; whilst in the laboratory the most simple contrivances are employed. To so great an extent is this the case, that the most serious duties of the professional chemist, that of deciding on the presence or absence of a poison in criminal cases, can be performed with apparatus costing but a few pence.

Our object has been to entice our youthful readers by giving them brilliant and yet instructive experiments; and we have endeavoured to avoid as far as possible all technical phrases. With respect to the apparatus required, we have given detailed explanations both of its use and construction, and when necessary have added cautions, so that by a little care the risk of accident may be avoided.

The first subject of our experiments is that of Chemistry, by which we are enabled to find out the characters and qualities of various substances, and also to learn in what respect they differ from each other. In former times Alchemy was followed by many, in the hope that they might discover some means of turning the baser metals into gold, of course entirely forgetting that such a discovery would have defeated its object by making gold of comparatively little worth, from its abundance.

Modern chemists have discovered only some sixty or seventy simple bodies in nature; and, as we have explained, these are called elements. The ancients applied this term to earth, air, fire, and water, three of which have been examined and proved to be made up or compounded of elements. In modern science these would, therefore, be called compounds. The chemist is able by analysis to find out what all compound substances are composed of, and by synthesis he is enabled to put elementary bodies together to form new compounds.

But the chemist has to depend on certain powers in nature, without which he would be perfectly helpless. Thus without Heat he could not fuse or dissolve many substances; without Light he could not judge of their appearance. Electricity and Magnetism are also essential in many of the changes going on around us. We have accordingly introduced a great variety of experiments with these four forces, and have also given directions for pursuing many of their applications, such as photography, electrotyping, &c. On the subject of Sound we have introduced some facts and experiments relating to music, musical instruments, &c.

There are many most interesting matters in connexion with air, water, and solid bodies both at rest and in motion, which have given rise to those branches of science called Pneumatics, Hydrostatics, and Mechanics. In our experiments on these subjects we have introduced some remarks on the steam-engine, and other modes of obtaining motive power, which will, we hope, prove interesting to most of our young readers.

In the course of our remarks we have explained the use of numerous philosophical instruments, and in many cases have given full directions for constructing them. Amongst these we may mention electrical machines and apparatus, galvanic batteries, the electric telegraph, microscopes, telescopes, stereoscopes, polariscopes, photographic apparatus, cameras, magic lanterns, barometers, thermometers, and many others which we need not name here.

Our last section, on Natural Magic, is meant entirely for amusement. Not a word have we said about science in it, although all the experiments we have named depend more or less upon some matters which have been referred to in previous pages. We have given in this section several tricks which we learned from three genuine Chinese, and have endeavoured to make as much fun as possible for the holiday amusements of our young friends.

Having thus explained the plan of our work, we have only to say that, in offering its pages to the perusal of our young friends and others, we do so in the hope that our humble attempt may facilitate the pursuit of experimental science. We have ventured to adopt a familiar style, in the belief that such would be generally acceptable. Whilst plenty of entertainment may be found, we trust that some of the fruits of the tree of knowledge may also be gathered. The study of nature at all times repays the inquirer, and, if followed with an intelligent and earnest disposition, opens out sources of pleasure which are not exceeded in any other pursuit; for in it we continually

> "Find tongues in trees, books in the running brooks,
> Sermons in stones, and good in everything."

J. W.

10, STATIONERS' HALL COURT, LONDON.
November, 1860.

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THE LABORATORY OF THE ROYAL COLLEGE OF CHEMISTRY.

EXPERIMENTS IN CHEMISTRY.

OXYGEN.

As we do not propose attempting to make our readers proficients in science, we shall omit giving details of *various* ways of obtaining the gases, &c., with which we intend experimenting; and shall only name the best, easiest, and simplest plan, leaving advancing students to seek for further information in the works of Fownes, Griffin, Turner, Brande, or Graham.

Oxygen gas affords us a great variety of beautiful experiments; but, before describing its preparation, we shall mention a few results obtained by very simple means which will illustrate some of its properties.

Experiment 1.—Into a common fire throw a teaspoonful of powdered saltpetre. At the instant the salt touches the red-hot coal, a most brilliant combustion takes place, owing to the *oxygen* contained in the salt leaving it to combine with the charcoal contained in the coals.

EXPERIMENT 2.—Obtain some zinc shavings, which you may easily get from a tinsmith, and hold some of these in the flame of a common candle. They will burn with a beautiful blue flame, and a fine white powder will fly off, which is called "Philosopher's wool." This experiment succeeds, because the air we breathe contains *oxygen* gas ; and, although the zinc and gas seem lost, such is not the case, for they have simply changed their state. The white powder contains both, and is the rust, or, as we say in chemistry, the oxide of zinc.

EXPERIMENT 3.—Under a common glass tumbler, with its mouth downwards, place a small piece of candle already lit. You will find that the light will soon go out, because the wick and tallow have, during their combustion, robbed the air of its oxygen.

EXPERIMENT 4.—A mouse confined inside a closed tumbler will die so soon as the air contained in the glass has lost its oxygen, inasmuch as the mouse consumes that gas by its lungs, as the flame of the candle did in our last experiment by combustion.

EXPERIMENT 5.—Throw a small piece of potassium into a basin of water. The oxygen in the water will leave it to combine with the metal, and a beautiful combustion will take place on the surface of the liquid.

EXPERIMENT 6.—To vary this, put two or three little pieces of potassium into a teaspoonful of ether, and throw the spoon and contents into a pail of water. The whole surface will immediately catch fire. The experiment may be repeated on a pond with still greater effect, and our experimentalist may thus teach his young friends the notable feat of "setting the Thames on fire."

A plan was proposed by Mr. McIntosh for the purpose of destroying the shipping and harbour of Sebastopol during the late war. A bombshell filled with ether, and containing some pieces of potassium, was to be fired from a mortar, and on striking the sides of the ships in the harbour it would on breaking have produced the same result as that we have just described, and doubtless would have been destructive in its effects. The reason of its non-application suggests that we should caution our young friends against danger ; for as ether is very inflammable, great care must be observed in its use. On trying the last two experiments, keep at least three or four feet from the water, lest the pieces of potassium should fly into and injure the eye at the moment of their touching the liquid; an accident which once nearly caused the loss of an eye to the writer. Never try the experiment near a gas or lamp flame, lest the ether should catch fire. The impossibility of trusting a quantity of these dangerous substances in the hands of our brave, but often careless "tars," prevented the employment of this plan.

Experiment 7.—Fill a tumbler with cold water, and turn it upside down in a basin of water, so that the liquid shall still remain in the glass. This is easily done, by keeping the mouth of the glass under water after the air has all passed out. Into the glass pass a few small pieces of fresh plucked mint, and place the whole in the direct rays of the sun. On examining the tumbler after a few hours, bubbles of gas will be found at the top. This gas is pure oxygen, obtained by the action of the vital power of the plant, aided by the sun's heat and light. On this principle the common aquarium is arranged, its plants affording oxygen to the fishes, &c.

We have thus shown, by these experiments, how oxygen may be found in a salt, in air, and in water; and it may be interesting to observe here, that we are indebted to this gas for our life, for the colours of the flowers, the existence of our plants and trees; and, in fact, it is the most abundant, and perhaps the most useful agent on the face of the earth. We shall now show how you may obtain this gas in quantity for further experiments, for which the following apparatus is necessary.

For making small quantities of oxygen, a retort is used, which is intended to hold the mixture from which the gas is produced.

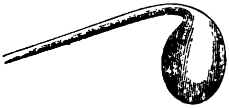

Fig. 1.

Fig. 1 illustrates one of these vessels. They vary in size, but one holding a quarter of a pint will answer the purpose.

A more simple arrangement is that of a test tube, into the neck of which a cork is fitted with a bent tube, either of metal or glass. Fig. 2 represents one of these.

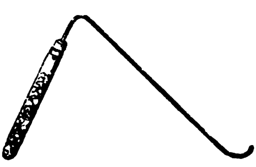

Fig. 2.

Another, and still better plan, is to employ a Florence oil-flask. Empty ones may be bought for a penny each at the oilman's, and they should be carefully cleaned, by either a strong solution of soap and soda, or some sulphuric acid. After all the oil is washed out, fit into the neck of the flask a good cork; through the cork bore a hole by means of a wire, or by a red-hot skewer. Into this a bent glass or pewter tube, about eighteen inches long and a quarter of an inch wide, must be fitted, so that the whole shall present the appearance represented in Fig. 3. We recommend this plan to our young friends, as being the cheapest and simplest. We have made oxygen by this simple apparatus from the smallest quantity to eight or ten cubic feet at a time, and the arrangement can be used for numerous other purposes.

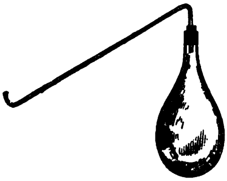

Fig. 3.

Either of the above being employed to hold the materials, you will also require some means of obtaining heat. For this purpose a gas jet will do, but a spirit-lamp answers better. The instrument makers sell glass ones at various prices, but a common tin oil-lamp costing about sixpence, will answer perfectly well. Since the change in the Excise laws, methylated spirit is largely used by chemists. The lamp is two-thirds filled with spirit, and a common cotton wick is employed. Fig. 4 gives an idea of the most approved form of the glass lamp, with a cap, whose use is to prevent the loss of spirit by evaporation when the lamp is not burning.

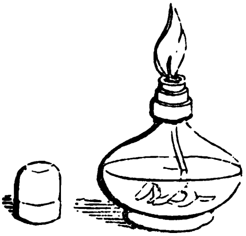

Fig. 4.

To collect the gas you will require what is called a pneumatic trough. A tin, or zinc box, measuring a foot high, wide and deep, will answer very well; and a tray should be made to hold the jar, or bottle, while filling with gas. Our diagram (fig. 5) gives an idea of the construction of those generally used by chemists; and an intelligent tinsmith will be able at once to construct one on inspecting our illustration. In practice, however, our young friends can do just as well with a common basin or a pail. We always use the latter ourselves in preference to any other arrangement. In such a case you must hold the gas jar by the hand whilst the gas passes into it. The shelf of the pneumatic trough saves this trouble.

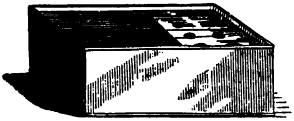

Fig. 5.

The vessels intended to receive gases are called gas jars. These may be of any kind, from a common tumbler to one of the usual sort represented in fig. 6. The green-glass preserve and sweetmeat jars answer exceedingly well for this purpose, and in some cases the tall glass vessels used by confectioners, as window show-glasses, may be used with advantage.

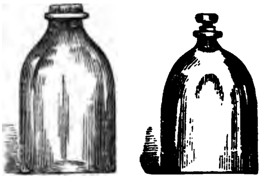
Fig. 6.

An arrangement of some kind must be provided to hold the retort or flask over the lamp, when gases are produced by heat. These are called retort or ring stands. Fig. 7 gives an idea of the kind usually found in laboratories. Our young friends can easily construct one of these by obtaining an iron rod three-eighths of an inch thick, and eighteen inches high, which should be fixed in a wooden foot. On this, rings of iron wire should be fastened, by twisting the wire thrice round the iron rod, and forming a ring by means of the other extremity. The wire should be of a size called No. 10 gauge in the trade. An inspection of our engraving will enable any one to understand the construction of one of these arrangements.

In some experiments with oxygen a holder is required, by means of which you can suspend phosphorus and other

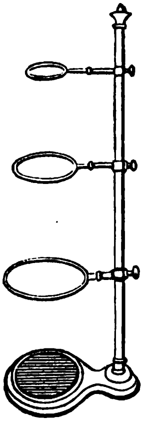
Fig. 7.

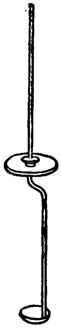
Fig. 8.

bodies in a jar of the gas. One of these is depicted in fig. 8. It consists of a cup of brass, attached to an iron wire. The further end of the wire may be passed through a cork, so as to form a handle or rest at the top of the jar. (See fig. 13, where one is represented in use.) Two of these should be obtained.

The mixture from which we obtain oxygen in quantity is made by pounding separately two parts of chlorate of potass and one part of black oxide of manganese; the two may then be mixed together, and kept in a well-corked bottle. When referring to this again, we shall call it the oxygen mixture.

Having thus described the apparatus required in making oxygen, we now proceed to explain its production.

EXPERIMENT 8. — *To prepare Oxygen Gas.* — Take either the small retort, test tube, or flask, and pour in a tablespoonful of the oxygen mixture; shake the vessel until the bottom is equally covered, then place the bulb of either vessel on the ring-stand, and dip the end of the stem or pipe, four or five inches beneath the surface of the water contained in the pneumatic trough or basin. You must then fill the spirit-lamp to about two-thirds of its bulk with methylated spirits, or spirits of wine; the former is cheaper. Having lit the wick, place the lamp so that its flame may just touch the bottom of the retort. In a few moments bubbles of air will pass through the water in the trough; these should be allowed to escape; the heat may be then gradually increased. The gas jars or bottles having been filled with water in the trough, are to be raised, so that their mouths may be over the end of the tube from which the gas is escaping, and yet *below* the surface of the water, so as to retain the liquid, as we explained in our Experiment 7. The gas will thus pass into the glass vessels, displace the water, and by filling

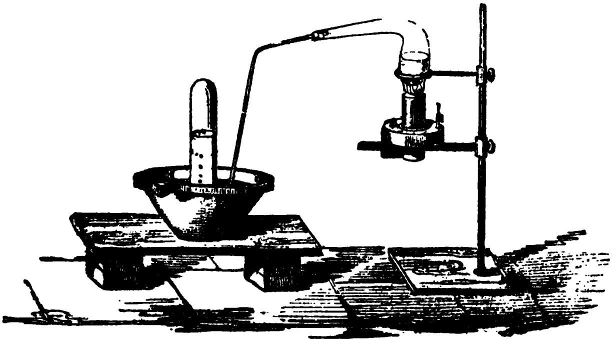

Fig. 9.

them one by one you will gradually acquire a stock of gas for future experiments. If you employ gas jars, they may be removed by slipping a plate under their lower edge, in the water of the trough, and raising them with the plate, retaining a little liquid so as to prevent the gas escaping. With respect to the bottles, they simply require corking before removal from the trough, and whilst their necks are under water.

A little practice will insure success; but to make our description more easily understood by the beginner, we annex a diagram (fig. 9), explaining the whole operation.

In the above diagram an Argand spirit-lamp is represented; a retort holds the materials, and through a bent glass tube fitted in the stem of the retort, the gas passes into a basin of water, and fills a glass jar. As soon as gas ceases to pass from the tube, the retort or flask must be immediately removed from the water, lest the liquid should rush back into the vessel, and so destroy it.

When oxygen is required in large quantities, a different arrangement is employed. The most common is that of a mercury bottle, into the neck of which a bent iron tube has been screwed. The bottle is then charged with the oxygen mixture, and heat is applied from a common fire. The black oxide of manganese is sometimes used by itself, as being more economical. To receive the gas, gasometers of various shapes and sizes are constructed. Our diagrams, figs. 10 and 11, will give you an idea of both the mercury bottle and a very convenient form of gasometer or gas-holder.

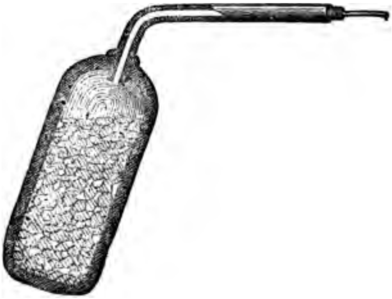

Fig. 10.

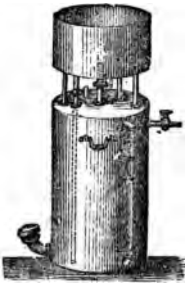

Fig. 11.

Having thus described to you the best plan of preparing oxygen in such quantities as it will be required, we shall presume that you have filled a few bottles, and are, therefore, ready to commence experimenting.

Experiment 9.—Dip a lighted taper into a jar of oxygen. The light will be greatly increased, and the wick will burn much faster than in the open air.

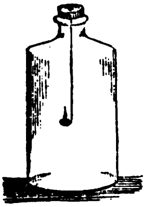

Fig. 12.

Experiment 10. — *To re-light a Taper.* — Blow out the light, so as to leave a little of the wick red-hot. Whilst in this state dip it into a jar of oxygen, and it will immediately re-light. This may be repeated many times with the same jar of gas. The tapers best suited for this experiment are those used for lighting gas, but a common tallow candle answers nearly as well.

Experiment 11.—Tie a small piece of charcoal to the end of a piece of thin brass or copper wire; make the charcoal red hot, by holding it in the spirit-lamp flame. When red-hot, immerse it in a jar of oxygen; a most beautiful combustion will take place, sparks flying off on all sides. Box-wood charcoal answers best for this purpose.

Experiment 12. — Put a small piece of phosphorus, not larger than a pea, into the phosphorus cup or holder (page 5, figure 8). Remove the glass stopper or cork from one of your jars of gas, and set fire to the phosphorus by means of a taper. Dip the cup into the jar immediately, and a splendid light will be produced. This forms one of the most brilliant experiments in chemistry. The heat often cracks the jar, and as there is no sure way of preventing this we recommend the use of the preserve or sweetmeat bottle, as being of little cost in case of breakage.

Experiment 13.—Put a small piece of sulphur into another holder, first lighting it, by heating the cup in the flame of a candle; introduce it into a jar of oxygen, and a fine blue light will be given out.

The two last experiments afford instances of the production of acids by burning the two substances in oxygen. These acids may easily be detected by tasting the water which is left on the sides of the glass whilst making the gas; this absorbs the fumes and will be found strongly acid. The name of oxygen is, in fact, derived from two Greek words,—"oxus," acid, and "gennao," to produce; the early chemists imagining that it was the sole acid-producer. The acids we refer to above are the phosphoric and sulphurous.

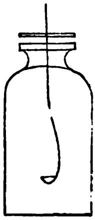

Fig. 13.

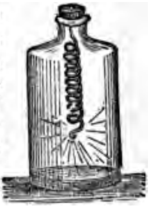
Fig. 14.

Experiment 14.—Obtain from the watchmakers a piece of steel spring, or a piece of twisted steel wire, as thin as possible and about ten inches long; to one end of this, tie tightly a piece of wick about an inch long, taken from the inside of a composite candle or a common taper. Pass the other end of the spring through a bung or cork, which will form a holder. On lighting the taper and dipping it into a jar of oxygen, the steel will catch fire, burning most brilliantly, and filling the interior of the jar with a red powder. This, in place of being an acid, as we obtained in our last experiment, is an oxide, or combination of oxygen with a metal. Whenever the term *oxide* is used, it simply means this, and is another mode of expressing the idea of *rust.* Rust of iron is produced by air and water, through their parting with oxygen to the metal. Our present experiment produces the same result by the action of heat.

Experiment 15.—Procure a common bladder of large size, and after cleaning the neck, by soaking the whole in warm water and rubbing with a dry cloth, tie tightly into it one end of a common stopcock, such as is used by gas-fitters. The bladder may be filled with oxygen, by receiving the gas into a jar to which another stopcock is attached; but as that plan involves expenses too high, perhaps, for our young friends, we shall leave its use to those who can afford to purchase costly apparatus. One simple plan is as follows:—

After tying the bladder to the stopcock, drive out all the air it contains by gentle pressure, and leave it moist. Then tie to the end of the stopcock a piece of india-rubber tubing about two inches long. Into a wide-mouth bottle holding about a pint of water fit a cork which has had two holes bored through it, just large enough to receive two pieces of pewter gas-pipe. One of these must reach to the bottom of the bottle, and the other should just pass into its inside through the cork. The bottle, which we will call the purifier, should then be three parts filled with water; and having your retort or flask ready for making oxygen, attach its stem, by means of another piece of india-rubber pipe, to the pewter tube which reaches to the *bottom* of the bottle. The *short pipe* is to be attached to the *stopcock* of the bladder. The whole apparatus is represented in our subjoined diagram, fig. 15. On the right we have the Florence flask, in which the oxygen mixture is contained; in the centre the purifier, whose object is to retain any manganese or chlorine which may pass over; and on the left the bladder is observed in the process of filling. After all is prepared run a little melted cobbler's wax over the cork of the bottle, to keep it air-tight; then open the stopcock of the bladder. On lighting the spirit-lamp, the gas will pass from the retort through the water in the bottle, and proceeding through the stopcock will gradually fill the bladder; as soon as this is filled, remove the retort before you take the spirit-lamp away, lest the water might pass into it and destroy it. The whole apparatus described above will not cost above three or four shillings, and will be again useful, as we shall show you under the head of Hydrogen gas.

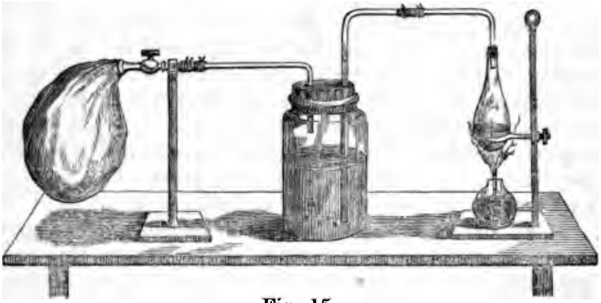
Fig. 15.

By an apparatus of this sort, we have often filled large gas bags; and with care the retort, or Florence flask, will last a long time, providing you apply the heat *gradually*, and leave the glass to get perfectly cool, before any attempt is made to clean it, which should be done by rinsing it with cold water. We always use the Florence flasks ourselves for the purpose. For the following experiments, a common tinman's blowpipe should be attached to the stopcock of the bladder, by means of a piece of india-rubber.

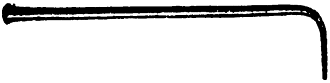
Fig. 16.

One of these blowpipes is represented in fig. 16. But a more convenient form of the arrangement is made, by attaching a straight piece of brass tube ending in a fine jet to the stopcock, by means of a piece of india-rubber tube, or instead of this, you may fix on a common tobacco-pipe stem. In either case, our fig. 17 illustrates the whole arrangement when in use.

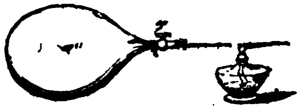

Fig. 17.

Experiment 16. — Take a thick piece of steel spring, and inserting the jet in the flame of the spirit-lamp, open the stop-cock and press the bladder under the left arm. This will force the gas through the flame; and by holding the end of the steel, at the point where the heat is strongest, the spring will catch fire and will melt, falling in all directions with splendid sparks.

Experiment 17.—Use a small cast-iron nail, in place of the spring, and a similar effect will be produced.

Experiment 18.—*The Oxycalcium Light.*—Instead of the spring, drive the flame on a small piece of common lime or chalk. A fine white light will be given off, far exceeding in strength that of a great number of gas-lights; and by these means, a large room may be most brilliantly illuminated. This plan is often used, for the purpose of obtaining a light in the magic lantern, instead of the oxyhydrogen light, of which we shall speak hereafter. By holding the hands, or allowing the hair of the head to fall in front of the light, most laughable effects of shadow may be produced; the profile of the face is enormously magnified, converting a child into a giant.

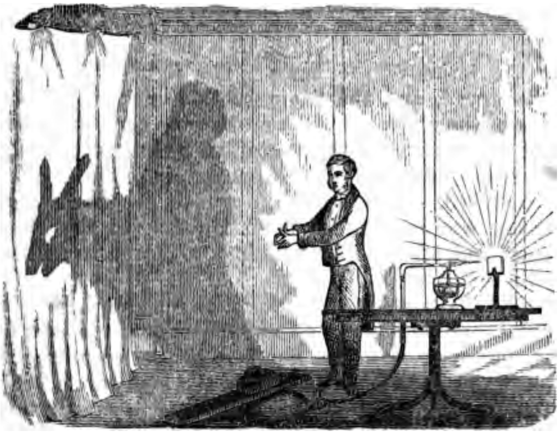

Fig. 18.

Experiment 19.—We shall here suggest an arrangement of the light which, by a little dexterity, may be made to afford plenty of fun to "children" of all ages. In our diagram (fig. 18) the light is supposed to be produced from the apparatus on the small table. The bladder containing the oxygen may rest on the floor, and be pressed by means of a board and weight. The rest of the arrangement is easily understood. If the hands and fingers are so arranged as to give a shadow representing the likeness of an animal, or of the human face, and a screen or sheet is suspended, so that the shadow may fall thereon, the spectators on the other side of the screen will see an enlarged image of the shadow; and by varying the position of the hands, &c., a vast variety of effects may be produced. Another plan is to let any member of the company place the face so that the shadow of the profile may fall on the screen. The rest of the company guesses who it is, under penalty of a forfeit should they make a mistake. The sheet, or screen, should first be wetted, so as to make it more transparent. We may just mention that an ox-bladder holding half a gallon of the gas, about a usual size, will last about twenty minutes; and, by having a few ready filled, you may maintain the light as long as you please.

Experiment 20. — *Combustion of Zinc.*—Take some zinc shavings, and having lit them, blow on the flame some oxygen from the jet. A most beautiful combustion ensues, which affords a brilliant experiment.

Experiment 21. — *The Bude Light.*—Into the inside of an Argand gas or oil-lamp tube, fit a cork so that no air can pass to the inside of the flame. The light will thereby be nearly destroyed, and the flame become smoky. If you now make a small hole through the centre of the cork, and introduce the jet of the oxygen bladder, permitting the gas to pass gently up the Argand tube, instead of common air, a fine white light will be observed. This has been named the *Bude Light*, by Mr. Gurney, who has applied it for illuminating the Houses of Parliament and other public buildings, although in a somewhat modified form.

As we have already remarked, our atmosphere contains oxygen gas, and without it all animal existence would perish. With it, however, is mixed another gas called nitrogen, the object of which is to lessen the action which would otherwise take place on the animal and vegetable economy. By this wise admixture we are enabled to live in what we may call a *sober* state of life. The stimulating effects of oxygen may be tried as follows :—

Experiment 22.—*Breathing of Oxygen.*—Place the stopcock of the oxygen bladder in the mouth, and, closing the nose by the fingers, breathe the pure gas. The whole muscular system will be excited, and a lively action sometimes induced. A still greater effect is found by using laughing gas, a compound of oxygen and nitrogen, which we shall speak of in our next section.

The experiments we have thus brought before you will teach the qualities and nature of oxygen; but before we close them, we must remind you of some occurrences in daily life in which this gas plays a very important part. The reason our tall chimneys produce so great a heat in the furnace is, that they draw the air rapidly through the burning coals, and so afford a rapid supply of oxygen from the atmosphere. The same is true of the steam blast of the locomotive, the bellows of the smith, and the smaller ones used by our housemaids in making the fire in the grate burn up quickly. Indeed, our respiration is somewhat of a similar kind of process; for each time the chest heaves, a supply of air is drawn to the lungs, which, as we shall afterwards explain, enables our food to "burn" in, and to give heat to our bodies. The intense heat of the iron furnace is produced by driving air rapidly through the fire by means of immense air-pumps or fans. Vegetable growth and putrefaction are due to the action of the oxygen of the atmosphere which surrounds us. And, in fact, to name all the effects due to this interesting agent, we should have to detail to you almost all the operations going on daily on the face of the earth. We cannot refrain from reminding you, how astonishing must be that Wisdom through whose arrangements so many effects are produced by the action of one substance.*

NITROGEN.

Having spoken of what we may call the active ingredient of the air in our last section, we now propose to introduce some experiments with a gas also found in the atmosphere in much larger proportions, but whose use is to temper, or, if you please, to tame down the effects of oxygen.

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* Before closing our remarks and experiments on oxygen, we must urge our young readers to make it a rule to clean all their apparatus on ending their experiments. Take care to let all glass vessels get cool before washing. Use plenty of cold water to cleanse them; and dry your vessels by draining them, and then by wiping the outsides with a soft towel.

Nitrogen derives its name from two words, signifying "to produce nitre," from which, indeed, nitrogen may be obtained. It is also called "azote," which means "depriver of life," for this gas we cannot breathe without risk of instant death, not because it is poisonous, but rather through its not possessing life-giving or sustaining powers.

It may be obtained in various ways, but the following is the easiest plan :—

Experiment 23.—*To procure Nitrogen.*—Take a tumbler, a tall glass jar, or a jar such as are used as show-glasses by confectioners; place this full of air, with its mouth downwards, near a soup plate, or basin filled with water, and have by you a jug of water, to replace any which will be driven into the vessel during the experiment; then, on a small piece of wood, cork, or in a common thimble, put a piece of phosphorus, light the phosphorus, and let it swim on the surface of the water in the plate, placing over it the glass jar. A few bubbles will at first be driven out, but eventually the phosphorus consumes all the oxygen in the air, and the water will rise inside the glass. The gas left is nitrogen gas, which will become clear by leaving it for a quarter of an hour over the water.

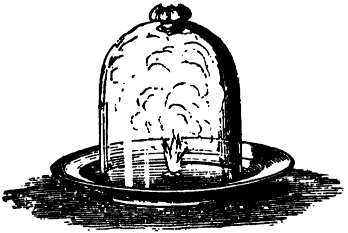


Fig. 19.

Our diagram represents the glass jar in which the phosphorus is burning. As the water rises inside the glass pour more into the plate, until it ceases to pass into the jar, otherwise air will enter, which would prevent your obtaining the nitrogen in a pure state.

Experiment 24.—Nitrogen will not support combustion. To prove this take a smaller glass vessel, fill it with water, and allow the gas you have just obtained to pass from the large to the small vessel. This is done by holding each in a pail of water, with their mouths beneath the water surface, but the large one underneath the smaller, and by raising its lower edge, till its gas passes into and fills the small one. When filled lift it gently, still with its mouth downward, from the water. Introduce now a lighted taper, which will be immediately extinguished.

Experiment 25.—Four parts of nitrogen with one of oxygen will produce five parts of common air; in fact, this is just such a mixture as forms our atmosphere. To try this, divide a glass jar into five parts, by pasting strips of paper outside. On passing into the jar the two gases in the above proportions, after the manner named in our last experiment, common air will be produced, which can be tested by a candle, as mentioned in Experiment 3, and compared with another glass jar of air of the same size, when you will find that the candle will burn for the same length of time in each.

These experiments are sufficient to show you the qualities of nitrogen in its pure state; and although we have only selected three, you must not suppose that this is all we can afford with this gas. On the contrary, we shall have to show you that it is found in all animal bodies, also in hair, horns, feathers, coals, and some trees. Ammonia, nitric acid or aquafortis, prussic acid, bread, and a vast variety of other substances, contain it; but as we shall speak of some of these under separate heads, we shall next present you only one of its forms, that is, when it is combined with or united to oxygen,—we mean, that of "laughing gas," which is an oxide of nitrogen, for the making and use of which we shall give full directions, accompanied with all necessary cautions.

Experiment 26. — *To procure Laughing Gas.* — Put two ounces of nitrate of ammonia, which you must obtain from an operative chemist, into a retort or Florence flask with a bent tube. (See figures 1 and 3.) Place this on the ring-stand, and let the stem of the retort or flask dip into the pneumatic trough, or in a basin. Instead of using cold water in these, a solution of two ounces of sulphate of iron or green vitriol dissolved in a gallon of warm water should be employed, the object being to purify the gas as it passes through the liquid. A gas jar open at one end, and corked at the other, is now filled with the water in the trough, and arranged so that the stem of the retort shall dip under its lower edge. (See fig. 9.) A gentle heat is now to be applied to the retort by means of the spirit-lamp till the salt contained in it melts. Laughing gas will then pass over and will gradually fill the glass jar, of course driving out the water. When no more gas passes over, remove the retort from the ring-stand, and let the jar of gas stand over the water for some time, so that any gases present, which if breathed might do you serious injury, may be absorbed. You will observe that the process is exactly like that used for making oxygen, with the exception of our last-named precaution, which you must never fail to observe.

Experiment 27.—*To breathe Laughing Gas.*—Never try this experiment, unless, at least, two persons are present beside yourself; and secure the person who is about to breathe the gas, to a post, by a rope fastened round the waist. Have ready a cork, which will just fit the neck of the glass jar you have filled with gas, and into this cork fit a piece of pewter tube, which must pass through a hole bored in the cork. To this a piece of india-rubber piping about three feet long should be attached, ending in a small piece of metal tube, which will serve as a mouth-piece. Our diagram, fig. 20, will explain the construction of the arrangement. On the right, you observe the pneumatic trough, in which the jar of gas stands. From the jar the india-rubber tube passes, and through this, the person taking the gas, inhales it into the lungs.

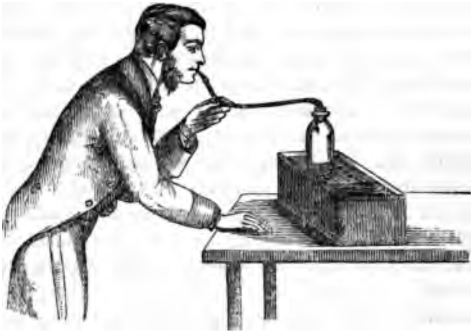


Fig. 20.

The usual plan is to transfer the gas to a bladder. This may easily be done by using the arrangement described and illustrated in fig. 15. We recommend the above plan as the safest, as no danger can arise from the presence of any other than the gas you require; whilst a bladder does not offer the same chance of safety for reasons which it would be tedious to state to our young friends. After removing the cork from the jar and substituting the one just now described, the person taking the gas should place the mouth-piece in his mouth, close the nostrils with the fingers, and inhale the gas into his lungs, until you observe a peculiar appearance in his eyes, say after a few seconds of time. Remove now the pipe from his mouth; and leave him to give way to his own feelings. The most laughable results sometimes occur; and that you may have some idea of these, the writer gives here an account of a scene which he witnessed a short time ago. Several persons having desired to take the gas, each in turn was fastened by a rope to a strong pillar. Some, after breathing the gas, commenced the most extravagant laughter; others were desirous of fighting; one stripped off his coat, and would have done serious damage to the faces of his neighbours had they not kept out of the way; and one young man attempted to kiss the ladies present, showing no symptoms of choice as to age or beauty. Altogether the effects are always highly amusing; each person seems to exhibit the peculiarities of his character in their most exaggerated form. In most cases the effect soon passes off; but we must warn those of our friends who are of a highly sanguine or nervous temperament, either not to partake of it at all, or to do so to a very moderate extent. We do not advise its use by the fair sex, under any circumstances.

Experiment 28.—Another and easier mode of producing the same result is, by placing a little ether in a bladder full of air, and supplied with a stopcock and mouth-piece. On breathing the vapour very similar effects to those we have described follow, and the same precautions should be observed. The vapour of ether has similar effects to that of chloroform.

In giving the above directions, we would remind our young friends that carelessness may produce unpleasant results. We had almost determined, for this reason, to omit describing the process; but knowing that young folks will try experiments with laughing-gas, if they have the chance, we trust we have erred on the right side by putting them in possession of the safest plans which can be adopted, and by recommending the exercise of discretion in the use of them.

HYDROGEN.

A large number of experiments may be made with this gas. It is found in water, coals, oils, and almost every animal and vegetable body. Before commencing our experiments, we must remind our young reader that we have now to deal with what we shall call a *dangerous* gas; and that all our precautions must be strictly observed, so as to prevent accidents. We shall have to employ an acid which has a very awkward effect on the clothes. If, by accident, a little drop is spilled on the coat, or other cloth garment, it will turn it to a bright-red colour; but by putting a few drops of ammonia (spirits of hartshorn) on the spot, the original colour will be restored at once; so we also provide you with a remedy. Cotton, or linen clothes, are completely spoiled unless the acid is at once removed, by either dipping them in ammonia, or washing with plenty of cold water. To impress this fact on the minds of our readers, and to prevent the destruction of shirts and shirt sleeves, we shall relate an anecdote.

Some years ago the writer took into his employ a young lad, with the intention of converting him into a chemical assistant. The youngster being very intelligent, had, amongst other things, observed the effect of acid in whitening cotton. He unfortunately determined to try the effect on one of his brown cotton shirts. A few days afterwards, he was told to bring a boat round to the end of our garden, and to look spruce and clean, as some ladies were going on the water. He donned this newly-bleached shirt, but before a dozen strokes of the oar had been taken, we observed a noise of cotton rushing to slits; and, alas! the shirt was soon demolished, a great portion flying off his back in powder on the water, to his intense mortification. He had whitened his shirt with acid, but had forgotten to *wash it* perfectly with cold water afterwards. "Verbum sat sapienti"—A word to the wise is sufficient. With these preliminary cautions, we now proceed to experiment with hydrogen, first giving directions as to the best way of obtaining it.

EXPERIMENT 29.—*To procure Hydrogen.*—Into a common basin, half-filled with water, throw some iron nails, and add some sulphuric acid. A large quantity of hydrogen will be given off; and, if a lighted match be applied, the gas will take fire. This gas is obtained from the water, in every nine pounds of which one pound of hydrogen is found. It derives its name from two Greek words—"udor," water, and "gennao," to produce. The remainder of the nine pounds of water is oxygen gas, with which we have already experimented.

EXPERIMENT 30.—*Hydrogen Gas Bottle.*—Any bottle holding about a pint will answer the purpose; but two different tubes must be made to fit into the neck. Bore two corks, and into one fix a pewter pipe, about eighteen inches long, and a quarter of an inch wide; and into the other fit a small glass tube drawn to a fine point, so as to serve for a jet. To make the glass jet, heat the middle of a piece of glass tube, eighteen inches long, in the flame of a spirit or gas-lamp, and when red-hot draw the glass apart in the middle. You will thus have two pipes, closed at one end. You must now break off the little point at the fine end, and you will thus obtain a glass jet. Instead of this you may fit a common tobacco-pipe into a cork, and fix this to the neck of a ginger-beer or glass bottle, and it will answer equally as well.

Fig. 21 represents one of these, made after the plan we have described, and fig. 22 one of those sold by the instrument-makers. It has two necks, and in one is placed a little funnel, for a fresh supply of acid, and in the other neck a jet, either of glass or metal.

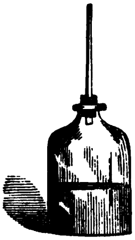


Fig. 21.

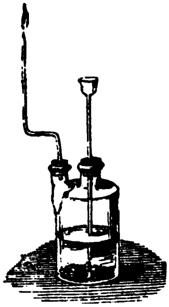


Fig. 22.

The above will be useful for a variety of purposes, but one of the following must be made, for supplying quantities of hydrogen for our future experiments.

Fig. 23 is a bottle to which a pewter tube and cork have been fitted, the tube being bent into the form represented in the diagram. Common tin gas piping answers very well. Fig. 24 is only a modification of this form of hydrogen bottle.

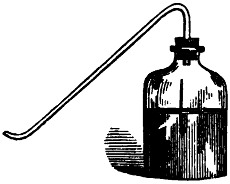


Fig. 23.

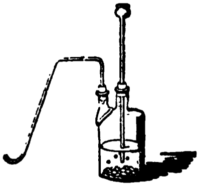


Fig. 24.

Experiment 31.—Into bottle (fig. 21) put a few small pieces of zinc, or a quarter of a pound of iron nails; nearly fill it with cold water, and then add gradually a little sulphuric acid, and replace the cork and jet. Hydrogen will be at once given off; but as it will be mixed with air, allow it to escape by the jet for about three minutes. Be cautious to observe this before you apply a light, otherwise you may burst the bottle, and seriously injure yourself. When safe, apply a light to the top of the jet: the gas will burn, but give very little light.

Experiment 32.—Hold a tumbler or any cold glass vessel over the jet; its inside will soon become covered with steam, through the gas you are burning combining with the oxygen in the air, and so forming water.

Fig. 25 illustrates an elegant mode of producing water by the combustion of hydrogen. Our young friends, however, will be enabled by the simple means we have named to obtain the same result on a small scale.

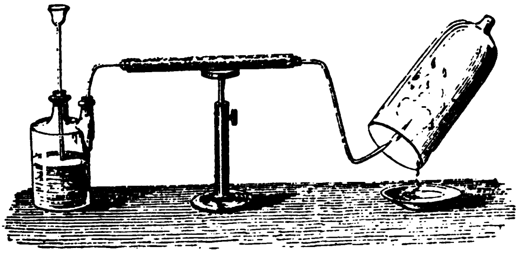


Fig. 25.

Experiment 33.—*Music from Hydrogen Gas.*—Hold a glass tube, varying from half an inch to three inches in the bore, and about eighteen inches long, over the flame of the jet. You will thus obtain musical sounds, which vary according to the sizes of the tubes. You may, by raising or lowering the pipes, find the sound of the cornopean, flute, railway whistle, &c., to any extent you please, which will afford great amusement to young folks. Our fig. 26 illustrates the mode of conducting this interesting experiment.

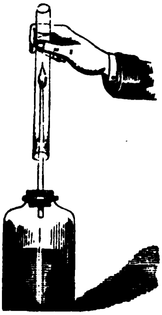


Fig. 26.

An inventor once proposed to apply this arrangement for the purpose of supplying church-music, in place of an organ; but it is to be feared that some variety of sounds which *might* be produced would by no means assist a devotional frame of mind.

Experiment 34.—*Coal Gas from Water.*—Remove the cork and jet from the bottle, and pour into it half a teaspoonful of ether, instantly replace the jet, and apply a light. You will find that the flame, which before gave no light, has now become a complete gas-light. This is because you have given some solid matter to the flame which it had not before. The ether contains charcoal, and this, combining with hydrogen, produces the effect. Coal-gas is composed of charcoal and hydrogen, the charcoal being obtained from the coals in the usual mode of making gas.

EXPERIMENT 35.—Every candle is a small gas manufactory, and you may even lay on gas-pipes from it. Thus, place in the flame of a candle, just over the wick, a piece of glass tube, 1-8th of an inch in the bore, and four inches long. The gas will pass from the centre of the flame through the tube, and may be lit at its further end. Fig. 27 illustrates the manner of carrying out this experiment.

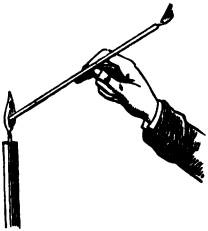


Fig. 27.

EXPERIMENT 36. — *To make Coal-Gas.*—Procure a tobacco-pipe, and fill the bowl with pieces of coal, each not larger than a pea; cover the top with clay, well pressed down, and place the bowl in a fire, so that the stem may project from the grate. In a short time a dark-coloured smoke will issue from the jet, to which set fire, and you will obtain a gas flame, producing a good light.

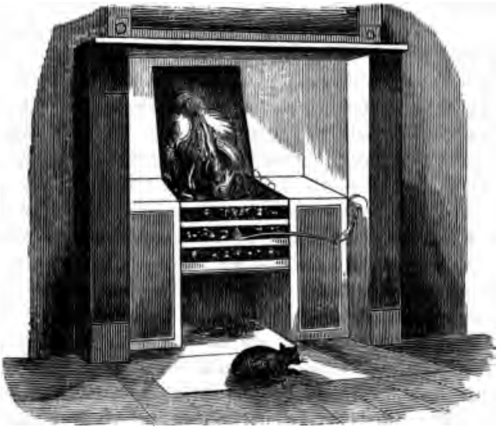


Fig. 28.

The above experiment explains the usual mode of obtaining the gas which is burnt in our streets and houses. Large iron vessels from six to ten feet long are built in furnaces, and into these retorts, as they are called, coal is thrown. The front of the retort is *then carefully* closed, and by means of a pipe the gas produced by heating these vessels is carried to a purifier, which retains the impurities passing over. The gas is then stored in large gasometers, and supplied to customers by means of mains placed in the middle of the streets, from which smaller pipes are laid on, reaching to the houses on either side. About 10,000 to 12,000 cubic feet of gas are obtained from twenty hundred-weight of coal.

The quality of gas varies very much; that, for instance, supplied in Glasgow has the power of giving twice as much light as the same bulk of London gas does. It is made chiefly from a coal called "cannel," which always affords a gas rich in charcoal.

Experiment 37.—*To collect Hydrogen in quantity.*—Use the bottle with the bent tube, represented in fig. 23; charge it with water, zinc or iron, and sulphuric acid, and allow the end of the tube to dip in the water of the pneumatic trough. By filling jars with water, and allowing the gas to pass into them after the usual manner, a quantity of hydrogen may thus be procured for further experiments. The confectioners' long show-glasses serve well for the purpose. In making hydrogen always take care that the air has passed away from the generating bottle before you attempt to collect the gas in the jars, otherwise the mixture will be explosive, for reasons we shall presently explain. When the jars are filled, remove them from the trough, by slipping a plate beneath the lower rim and retaining a little water, so as to prevent escape of gas.

Experiment 38.—*Hydrogen Gas is lighter than Air.*—Lift one of the jars of gas carefully from the plate, with its mouth downwards; apply a light, and the gas will catch fire, and burn for some time. Take another jar of gas and turn it, so that the mouth shall be upwards; if you keep it so for a few seconds, the whole of the gas will escape, because it is much lighter than air. In fact, if you hold the face over the jar, you may feel the gas rush past, and by then testing with a light, you will observe that all the gas is gone.

Experiment 39.—*Gas Balloons.*—The operative chemists keep small balloons made of very thin skin. To fill one of these, use the purifier (fig. 15) described under the head of oxygen. (See page 10.) Attach the hydrogen bottle to it by means of an india-rubber connexion, and the balloon to the short pipe of the purifier. Fig. 29 illustrates the process. When the balloon is full, tie its neck with a string, and allow it to ascend. It will keep floating in the air for a long time. The reason of balloons filled either with this or coal-gas ascending in the air *is, that they* weigh, including the material of which they are made, less than does the same bulk of air. Balloons employed by aëronauts are filled with coal-gas, for the sake of cheapness;

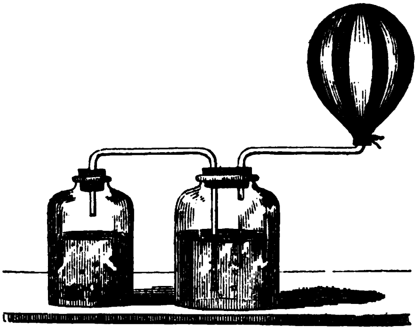


Fig. 29.

and although it weighs heavier than pure hydrogen, still it serves well enough when the balloons are large. Our young readers can procure these small balloons in the shape of fish, or men, and so, highly amuse their young friends. Sometimes these, on a large scale, produce comical effects. A few years ago, we saw a number of old women highly terrified by the descent of a "man" balloon near Islington Green. They doubtless thought that the veritable "man in the moon" had arrived at last.

EXPERIMENT 40.—*Soap Balloons.*—These are produced by blowing hydrogen through a strong solution of soap in hot water by means of a bladder; but great care is required, lest the tyro should blow *himself* up instead of the *soap*. And here we would urge you never to use bladders filled with hydrogen f they have been laid by for any length of time, as, being porous, they allow the air to pass through, and so produce an explosive mixture. Accidents have lately taken place from some of the toy india-rubber balloons, commonly played with by children, being filled with coal-gas, and coming in contact with flame.

EXPERIMENT 41.—*Explosion with Oxygen and Hydrogen.*—Procure a strong soda-water bottle, and fill it by means of the pneumatic trough or basin, with two parts of hydrogen, and one of oxygen. After the gases have expelled all the water, cork the bottle well, and wrap a thick towel round it. Now withdraw the cork, and apply a light; a very loud explosion will take place, and water will be formed, which may be traced inside the bottle in the form of dew.

In trying this experiment, never omit to cover the bottle with the towel, lest the glass, in case of bursting, should be driven into the hands. We have never known a bottle to burst after having once stood an explosion, but still, this simple precaution should always be attended to.

The explosions of gas which sometimes take place in our houses are owing to the mixture of the coal-gas, escaping from the pipes, with the oxygen contained in the air. Never take a light into a room in which there is a smell of gas; but at once open all the windows until all smell is lost. This will always prevent accidents taking place.

Cautions.—In experimenting with hydrogen, all lights or burning bodies should be kept at a distance from your vessels.

After concluding your experiments with any of the gases, fill every jar, &c. with cold water: this will prevent an accidental admixture; and lastly, the hydrogen bottles should be washed several times with water, to clean off a salt which the zinc or iron forms during the process of making gas. Cleanliness, order, and neatness are essential for safe and successful experimenting.

CARBON—THE DIAMOND, CHARCOAL, CARBONIC ACID, OR FIXED AIR.

As we do not intend to follow any special scientific arrangement, we shall next describe some very interesting experiments with a gas called carbonic acid gas, which is found in mines, distillers' vats, porter, ale, soda-water, &c., and to a small extent in the air. We shall only want the same glasses which we have used before, with a little marble, or chalk, and some hydrochloric, or as it is also called, muriatic acid.

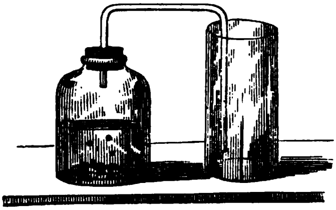


Fig. 30.

Experiment 42.—*Its production.*—Take the hydrogen bottle (fig. 23), and having cleansed it, throw in a quantity of marble, or chalk, broken into small pieces, but not powdered; on this pour a little water, and add half as much hydrochloric acid, so as to half fill the bottle. Fit in the pewter tube, and let it dip into a tall glass jar, so as to reach to the bottom, as in fig. 30. The acid will take the lime away from the marble, and the gas we want will pass into and fill the jar. This gas is very heavy, and will not escape until the glass is full, at the same time a small piece of card may just be placed over the mouth of the vessel, until you are ready to experiment with the gas.

Experiment 43. — Dip a lighted taper into the jar; the flame will be immediately extinguished.

Experiment 44.—Into a glass jar put a small piece of taper or candle, by tying it to a wire, and let the candle rest at the bottom of the jar, after having first lit it. Now take another jar filled with the gas, and pour its contents into the first one, in the same way as you would pour out water. Owing to its great weight the gas will pass into the vessel holding the taper, and extinguish the flame. These two experiments illustrate the deadly nature and weight of the gas; and suggest very simple means of preventing loss of life, to persons who have to descend into mines, vats, or other places where this gas is often found. (See figs. 31 and 32.)

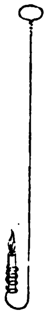


Fig. 31.

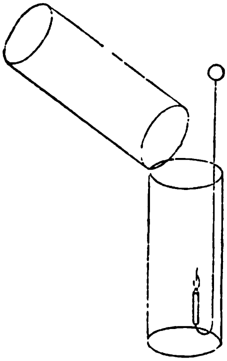


Fig. 32.

Experiment 45.—Half-empty a jar of this gas by tilting it on one side for a few seconds; then dip in a lighted taper. It will be found that the taper will burn until it reaches the part where the heavy gas is, when it will at once go out. Thus, any one descending a mine with a candle *beneath* his mouth, will at once perceive when he arrives at a dangerous part, by watching the candle he is holding; whereas, supposing he has the candle fixed in his cap, as many miners have, he will be suffocated before he is aware *of his* danger. (See fig. 33.)

During the autumn of 1859 five persons were nearly suffocated on board the Rothsay steamer "Ruby," through breathing this gas; and many persons yearly lose their lives through the same cause. It is produced from our lungs, during the burning of candles and gas, and in our furnaces and fireplaces, as we shall show by our next experiments.

Fig. 33.

EXPERIMENT 46.— Pour into a small glass a little lime-water, and then, by means of a glass tube, blow from the mouth into the water. After a short time the lime-water will become milky, owing to the carbonic acid driven from the lungs combining with the lime, and forming chalk.

Our bedrooms towards morning have more of this acid in the air than we would find on our retiring to rest; and many infants have died from the effects of this gas passing from the breath and bodies of their parents whilst in bed.

EXPERIMENT 47.—To show that the gas from our lungs is the same as that obtained from marble, pour a little lime-water into a jar of gas prepared as before (see Experiment 42). On shaking up the water with the gas, you will have the same result; chalk will be formed, and if afterwards you pour into each glass a little hydrochloric acid, you may observe the gas again given out and passing off into the air.

EXPERIMENT 48.—Burn a piece of charcoal as described in

Experiment 11, in a jar of oxygen, and then pour in some lime-water; chalk will at once be formed, proving that carbonic acid gas is produced by bodies containing charcoal, such as coal, gas, candles, &c., when they are burning.

Experiment 49.—Arrange a piece of apparatus as in the diagram, fig. 34. On the right is a small funnel suspended over a candle; the funnel is connected with the purifier used in making oxygen (see fig. 15); and the air is drawn from over the lighted candle through lime-water contained in the purifier, by sucking at the small tube. The gas produced by the burning candle will form chalk in the purifier with the lime-water; and thus you will see the products of combustion are the same as those obtained from the breath as expired from the lungs.

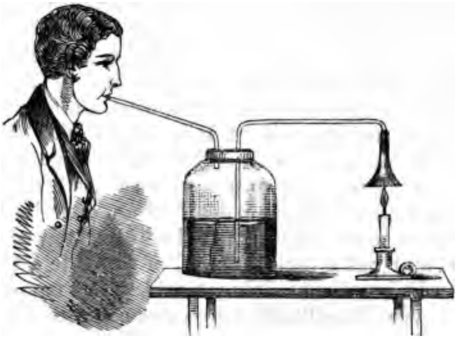


Fig. 34.

Experiment 50.—*Burning of the Diamond.*—Although most people are aware that charcoal or carbon is found in coals, few would believe that the most valuable of all our gems, the diamond, is composed of nothing but pure charcoal itself. To prove this, take a waste diamond, which may be bought for three or four shillings at a lapidary's, and fixing to it a piece of platina or iron wire hold it till red-hot in the spirit-lamp flame, urged by a blow-pipe; then plunge it in a jar of oxygen gas, where it will rapidly burn and produce a brilliant white light.

Experiment 51.—Remove the diamond holder from the jar, and pour in a little lime-water; shake it up with the gas. You will at once perceive chalk to be formed, and thus have proved that the diamond is simply carbon, which during combustion produces carbonic acid, exactly the same as that produced by the lungs or during the burning of a candle. The diamond may be used a number of times by only keeping it for a short time burning in the jar.

EXPERIMENT 52.—*Charcoal from Loaf Sugar.*—Our bodies are in some respects walking fireplaces, for by the burning of our food in the lungs we maintain the heat of our system. In warm climates, where the air is hot, less charcoal food is required, but in Greenland and other northern climates, food containing plenty of charcoal is necessary; thus the Esquimaux delight in train-oil, of which they take a prodigious quantity daily. An Arctic captain once invited one of these folks to dine with him, and offered him coffee, wine, and ale, all of which he rejected, but seeing an oil-can lying on one side of the vessel, his Greenland friend seized it, and never stopped until he had licked the pot clean. Our own food, such as bread, meat, &c., contains charcoal, and we now describe an experiment proving this. Dissolve some loaf-sugar in boiling water, so as to make a strong syrup; put a table-spoonful of this into a tumbler, and pour on it a little strong sulphuric acid. The moment the acid touches the syrup it will seize the water contained in the sugar, and set free the charcoal—sugar being composed of charcoal and cold water. In trying the experiment, place the glass on a large plate, so as to prevent injury to the table, the acid and charcoal generally boiling over the side of the vessel through the great heat produced. On allowing the glass to get cool, you can turn out its contents into the plate, and keep by you a specimen of *sugar charcoal.*

EXPERIMENT 53.—*Shirt Sugar.*—Cotton, linen, starch, sago, arrowroot, &c., are all composed of charcoal and cold water, and by very simple means you may change an old shirt, sheet, or pocket-handkerchief, into as much sugar as the article weighs. You must proceed thus :—Into a basin put a quantity of linen rags, cut and torn as fine as possible, and pour thereon some sulphuric acid. Leave the whole for a day or so, and then add a quantity of water, say ten times that of acid. Boil this mixture in a Florence flask for four or five hours, and when cool, pour its contents into a basin containing a little chalk and cold water; add powdered chalk until no more gas comes off. You must then strain the liquid through a sheet of blotting-paper or fine muslin, so that it may pass quite clear into a tumbler. On tasting it you will find that you have obtained syrup, and by boiling this for some time in a clean saucepan, very carefully, and putting it by to cool, you may turn out just as much sugar as your rags first weighed. We have made this experiment frequently; and if you carefully follow the directions we have given, you may easily obtain sugar wherewith to sweeten a cup of tea for your young friends, and when they have drunk it, you can tell them that they have been drinking an old shirt.

To make Filters.—We will here instruct you how to make a filter for straining liquids. Take a square piece of white blotting-paper, No. 1, and fold it as in No. 2, fig. 35; fold it again as in No. 3, and by opening out one fold you will have a filter as in No. 4, from which you can cut the pointed ends, and thus have the affair complete. The philosophical instrument-makers sell these ready cut for use in small packets.

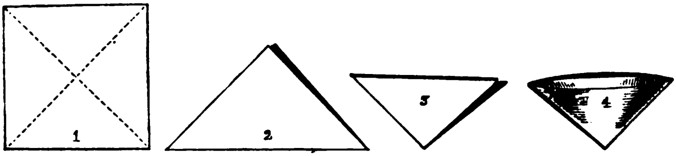


Fig. 35.

The lively taste of beer, ale, champagne, &c., is due to the presence of carbonic acid; soda-water, ginger-beer, and lemon kali, or sherbet, owe their effervescence to its presence. We shall give our friends here a "taste" of chemistry.

Experiment 54. — *To make Soda Water.* — Half fill two glasses with cold water. Into one put half a teaspoonful of carbonate of soda, and to the other about the same quantity of tartaric acid. Stir each till all is dissolved, and then pour the acid into the solution of soda; carbonic acid will be immediately disengaged, and, without waiting to philosophize further, drink off the mixture at once.

Experiment 55.—Another plan is to mix equal quantities of the soda and acid in a mortar, in the dry state, and then to cork up the powder in a clean dry bottle. A teaspoonful of this, dissolved in a glass of water, gives the same result as above.

Experiment 56. — *To make Lemonade.* — Proceed as in the last experiment, but add three or four times the weight of sugar to the mixture. On this pour a few drops of essence of lemon, and keep the whole well corked till wanted.

Experiment 57.—*To make Ginger Beer.*—Instead of essence of lemon, used in the last experiment, employ tincture or spirits of ginger.

Experiment 58.—*To make Orangeade.*—A most delicious drink may be made by pouring a wine-glassful of orange wine into a tumbler of water, and adding a teaspoonful of the mixture described in Experiment 55, together with a little powdered sugar.

Experiment 59.—*To obtain Carbonic Acid from Beer, &c.* —Put a little bottled ale, or porter, into a Florence flask, fitted with a bent tube. Let the tube dip into a tall, narrow jar. Heat the flask with the spirit-lamp gently. The carbonic acid will pass into the jar, and may be discovered by introducing a lighted taper, which will be immediately extinguished.

Experiment 60.—Let the gas pass into a little lime-water, and chalk will be at once formed, proving that carbonic acid is present.

It is the presence of this gas, produced in fermenting dough, which gives the bread its cellular appearance. The yeast added to the flour produces the carbonic acid in all directions, and forms the little holes we observe in cutting the loaf. While the bread is baking, the gas is all driven off by the heat. The gas is made at the expense of the flour, whose carbon combines with oxygen as the fermentation proceeds.

Experiment 61. — *Charcoal from Animal Matter.* — Into a tobacco-pipe bowl put some small pieces of bone; cover the top with elay, and heat it in a common fire till red-hot. When the bowl is cool, the contents will be found to be what is called "ivory black." During the process, gas will escape from the stem, which may be set fire to. It is very similar to coal-gas in every respect.

Experiment 62.—*Charcoal as a Filter.*—Charcoal has great power in taking into its pores gases of all kinds; and by means of it and a little sand a very simple filter may be made. Take a common garden pot, and put a small piece of sponge through the bottom hole, so as to fix in tightly. Then pour in and shake down some coarse gravel; on this put a layer of charcoal in pieces the size of a pea; over this about two inches of fine sand, then some coarse gravel, and lastly, at the top of the pot, a piece of clean linen cloth. If a string is tied round the pot, it may be hung up on a nail, and will act altogether as the cheapest and most effective filter you can get; costing not more than fourpence. Fig. 36 represents one of these simple contrivances.

Experiment 63.—This simple arrangement should be recommended by our young friends to their poorer neighbours, and thus they may make their amusements beneficial to others. Besides purifying the water, the filter acts as a cooler, especially if placed in a draught, owing to the porous clay promoting evaporation. To understand this, take a bottle of wine or water, and wrap a towel round it, which has first been well wetted. Now hold it at a little distance from the fire; and you will find, after some time, that instead of the liquid becoming hot, it is decidedly cooler to the tongue. Evaporation always produces cold,—hence the formation of dew.

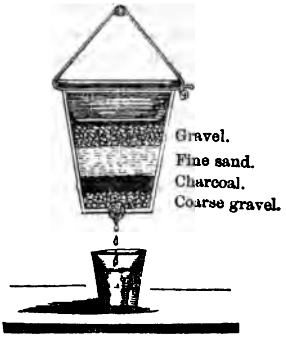


Fig. 36.

EXPERIMENT 64.—Fresh-made charcoal placed inside poultry, game, &c., after they are trussed, will preserve them sweet for a long time. Procure two dead rats, and on them place, to the depth of three inches, little pieces of charcoal. No smell will pass through, even in summer time, owing to the gases being absorbed by the charcoal. We have kept three rats this way four months, in a sitting-room, without finding the least inconvenience. Messrs. Stenhouse and Watson proposed to purify the air in hospitals by similar means; and respirators containing charcoal have been made for use in places abounding in foul air.

The antiseptic powers of charcoal make it an excellent tooth-powder. It has even been employed as a lozenge in cases of indigestion. Posts for use in farm-yards and as fences, are generally charred at the end before inserting in the earth, and the charcoal is found to prevent the decay of the wood.

Charcoal is largely employed in making gunpowder; but as we propose to speak of this hereafter, we shall leave the subject, together with that of gun-cotton, for another chapter.

Before concluding our experiments on charcoal, we must remind you of its value in nature. All plants and all animals, contain it; and, most singular to say, the very poison, carbonic acid, we cast from our lungs, becomes afterwards food for trees. As this gas is composed of two parts of oxygen to one of carbon, the trees select the carbon or charcoal, for *their* use, and send us back the oxygen *we* want in abundance. We make poison, and they undo our evil work. Three-fourths of every tree are thus gathered from the air, which, nevertheless, does not contain more than a fraction of its bulk of carbonic acid gas. It is to charcoal we are indebted for our success in obtaining metals from their ores; and our concluding experiment will enable you to understand the method of obtaining lead, iron, and copper, in a metallic state.

Experiment 65. — *Metals obtained from Ores.* — Make a little red-lead into a paste with charcoal, by means of some common oil; put this into the bowl of a tobacco-pipe, and heat it red-hot in a fire. After a little time the lead will be reduced; that is, the oxygen of the oxide of lead (see Experiment 14) will leave the lead and join the charcoal, forming carbonic acid. The lead you will find in the state of metal, at the bottom of the bowl.

CHLORINE.—COMMON SALT.—BLEACHING.

Chemistry presents us with more magical effects than any other branch of science. Who, for instance, would suppose that the salt we eat—the salt which gives the sea its peculiar taste,—could ever have been, and now is, the chief source of the riches found in Manchester and Glasgow? Such, however, is the fact, for from salt we obtain the most valuable bleaching agent—chlorine, without which the majority of our cotton mills would be unemployed.

Chlorine obtains its name from a Greek word "chloros," signifying green, that being the colour of the gas. It is heavier than air, and has a very pungent smell. We must here warn you against taking this gas into the lungs, as it has a most dangerous effect. Whilst experimenting with this gas do so in a large room, with the windows open, or in the open air. Should you unintentionally breathe it, just inhale a little spirits of hartshorn (ammonia), and gargle the throat with cold water and the white of an egg.

Experiment 66.—*Preparation of Chlorine.*—Into a Florence flask put a little common salt and some oxide of manganese; pour in some water, till every part of the bottom of the flask is well wetted; then fit a cork and bent-glass tube into the neck, first pouring in some sulphuric acid; apply a very gentle heat. The flask will soon be filled with a green-coloured gas. A *dry* bottle should now be placed under the tube, in which you may collect the chlorine for experiments. Take care to use a *glass tube*, as a pewter one would be destroyed.

To bend the glass, take a length of glass tube, say eighteen inches, and hold it in the flame of the spirit-lamp. When red-hot bend it twice, until it assumes the shape represented in fig. 37. If careful, you will easily succeed.

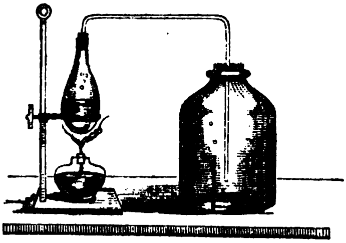


Fig. 37.

When the bottle is full of gas, put in the glass stopper, first greasing it, and the gas will thus keep for any length of time. Mark the bottle outside as containing chlorine, if you do not at once use it, so as to prevent any mistake.

EXPERIMENT 67.—Instead of common salt and sulphuric acid, employ hydrochloric acid and oxide of manganese, and proceed as before.

EXPERIMENT 68.—A still easier way is, to place in the flask some chloride of lime and muriatic acid, mixed with a little water, and proceed as in Experiment 66. The chlorine is soon driven off from the bleaching powder, and by employing this plan you will avoid both dirt and trouble.

Having prepared a few bottles of the gas, the following experiments will show its characters:—

EXPERIMENT 69.—*Chlorine destroys Vegetable Colours.*—Take a piece of any coloured glazed calico, moistened with water; dip it into a jar of chlorine, and the colour will immediately disappear.

EXPERIMENT 70.—Dip a piece of red blotting-paper, or a portion of the dark-blue paper used by grocers, both first wetted, into a jar of the gas, and they will speedily become white.

EXPERIMENT 71.—*To bleach Brown Calico.*—Boil a piece in a little soda and water for a short time, rinse it carefully in cold water, then immerse it in a solution of chloride of lime (bleaching powder). It should now be put in water, to which you have added as much sulphuric acid as makes the water taste sour. By repeating this process twice, and at last washing with plenty of cold water, the calico will attain a pure white. By this process all the bleaching of calico and other cotton goods, is carried on in the north of England and Scotland.

Perhaps some of our young friends may be inclined to try the bleaching of their cotton dress. We warn them to be careful to wash any article they bleach in abundance of cold water, or they may have the same result as we mentioned in our introductory remarks on hydrogen gas. The laundry women of London use bleaching powder largely, and old and young bachelors *find out* its effects by often unwillingly thrusting their hands through, what should be, the sound cloth of their shirts and handkerchiefs.

EXPERIMENT 72.—*Flowers may be bleached by Chlorine.*—You will succeed best by using roses, or rose leaves (kept by the chemist), for winter experiments. Moisten the flower well with water, dip it into a jar of chlorine, and it will soon lose its colour.

EXPERIMENT 73.—*The Magic Colour Glasses.*—In a tall glass jar dissolve a little litmus, or, what is better, a little indigo, in plenty of water. In another, dissolve a drachm of iodide of potassium, with a small quantity of arrowroot, or ready-made starch. The first glass will have a blue colour, and the second will be colourless. Shake up some water in a bottle of chlorine gas, by which the gas will be absorbed. Now pour half of this chlorine solution into the first glass, and the colour of the liquid will be destroyed; into the second pour the other half, and a fine blue colour will be produced, owing to the liberation of iodine, which always produces a blue colour when mixed with a *cold* solution of starch. By stirring the liquids, the effect is produced quicker.

EXPERIMENT 74.—We here suggest an interesting experiment, for the purpose of making our young friends neat experimenters. Into a tall glass jar pour some solution of litmus;

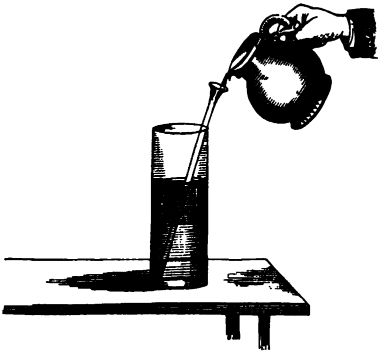


Fig. 38.

then, by means of a glass tube, pour in some chlorine water. That portion of the liquid which is reached by the chlorine will be bleached, whilst the upper part will retain its colour.

EXPERIMENT 75.—*To remove Fruit Stains.*—Wet the part stained with the chlorine solution, or chloride of lime dissolved in water. The marks will soon disappear. Wash with cold water afterwards, to remove the superfluous chlorine.

EXPERIMENT 76.—*Metal catches Fire in Chlorine.*—Into a jar of the gas throw some pieces of Dutch metal; they will immediately burn, forming a chloride of copper.

EXPERIMENT 77.—Use some finely-powdered antimony. It will present a very pretty appearance whilst falling into the jar.

EXPERIMENT 78.—*Burning of Turpentine.*—Wet a piece of blotting-paper with turpentine, and introduce it into a jar of chlorine. It will catch fire and give off abundance of smoke.

EXPERIMENT 79.—Introduce a lighted taper into chlorine in a glass bottle. It will throw off a red flame and dense sooty smoke.

EXPERIMENT 80.—On a small piece of blotting-paper, pour sufficient chlorine water to just wet it. On this put a very small piece of sodium. The metal will ignite, and by uniting with the chlorine, common salt is formed. The salt may be tasted by the tongue; and we may here remark that common salt, called by chemists chloride of sodium, is the source whence we obtain both the metal for chemical, and the gas for commercial purposes.

EXPERIMENT 81.—Put a piece of gold-leaf into a little chlorine water, and it will speedily dissolve, forming a solution of chloride of gold.

The foregoing experiments will give you an idea of the chief characters of chlorine. It is not so abundant in nature as oxygen, but as we have already mentioned, it is largely found in salt, and in the sea. In common salt we have an instance of one of those strange changes which take place on bringing different bodies into a state of chemical action. The metal found in salt would instantly destroy the tongue if placed on it. The gas obtained from salt, with which we have been experimenting, would cause instant death, if taken into the lungs, and yet when the metal and gas are combined, we have the harmless and useful salt which ever forms part of our body.

Chlorine, although long well known under a different name, was first investigated by Sir Humphrey Davy, and not long afterwards, Mr. Tennant, of Glasgow, found that it might be combined with lime, and so form a convenient bleaching material. Thus, a discovery which at first only interested scientific men has, by its application to commerce, produced astonishing results. In former days, it took from four to six weeks to bleach cotton goods in the air. At the present day you would find scores of pieces bleached to the purest white in some of the large calico printers' works, before you, if visiting one, would have had sufficient time to walk through the establishment in which the process was going on.

IODINE AND BROMINE.

IODINE and BROMINE are, like chlorine, found in sea-water, sea-weed, and in the coarse barilla or soda, and are obtained from these sources by a very tedious process. Besides being used in medicine, they are largely employed in photography. They offer few experiments to the young beginner, and we shall therefore confine ours to those just sufficient to illustrate their properties, leaving their uses to be treated of under the head of photography.

EXPERIMENT 82.—*The Vapour of Iodine.*—Put a few grains of iodine on a hot tile or shovel. It will immediately rise in vapour of a rich deep purple colour.

EXPERIMENT 83.—Repeat the experiment by heating a little iodine in a Florence flask. The iodine will rise in vapour, and be again deposited in crystals on the cool side of the flask. This is an instance of what is called sublimation.

EXPERIMENT 84.—*Blue Colour produced by Iodine.*—Put a small piece of iodide of potassium into a glass of water, with a little arrowroot or starch, and no change will take place. Now add two or three drops of sulphuric acid; the iodine will be at once liberated, and turn the starch of a blue colour.

EXPERIMENT 85.—BROMINE is known by its deep orange colour and strong smell. Put a little into a test-tube, and apply a gentle heat. The bromine will immediately rise in vapour.

FLUORINE—GLASS ETCHING.

We introduce an experiment or two which will enable you to etch glass, but first give directions for preparing hydrofluoric acid, which is the agent used for that purpose.

EXPERIMENT 86.—Take a piece of sheet lead, and make a square tray, by bending up its sides. The tray may be six or eight inches each way, with the sides raised two inches. Into this put some pounded fluor spar, and pour on some strong sulphuric acid. The spirit-lamp should be used to assist the process. Be very careful not to inhale the fumes, as they produce the most painful effects on the nose, eyes, and lungs. Fig. 39 represents the form of apparatus.

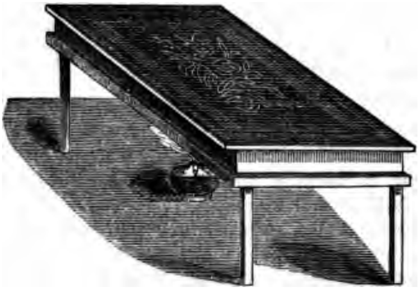


Fig. 39.

Experiment 87.—*To etch Glass.*—Cover a glass plate, say six inches square, with beeswax. On this make any drawing, by removing the wax by means of a knitting-needle, so as to expose the glass. Place this, engraved side downwards, on the tray described in our last experiment. The acid fumes will soon eat away the glass where exposed, and thus etch into it an exact copy of your drawing. Take care not to melt the wax by too much heat.

The best wax for the purpose is that obtained from wax candle-ends. This should be melted in a tea-cup, and run over the glass, the superfluous quantity being drained off. It is advisable to coat *both* sides of the glass, so as to prevent any action of the acid fumes which may escape. Do not attempt to etch with the needle until the wax is cold. If you are a good sketcher, you may produce some excellent results by first drawing with a soft black-lead pencil on paper, then transferring the drawing to the wax, by placing it face downwards, and weighting it at the top. The pencil-marks will thus adhere to the wax, and will direct you in the regularity of its removal by the needle.

PHOSPHORUS.

This well-known article is found chiefly in bones, but also forms part of wheat and other vegetable substances. We shall not speak of its production, because it can be easily purchased. We commence by warning you never to touch it with the fingers, as it gives fearful burns. Always cut it under water, and keep it in a glass stoppered bottle, filled with water, and covering every piece of phosphorus, as it so easily catches fire. When you wish to dry it, just press a small piece of blotting-paper on it, which will absorb the moisture.

Experiment 88.—Rub a small piece, by means of a pair of iron nippers, against a wall in a dark room; every mark will appear of a beautiful white light. You can thus write your name or draw a friend's likeness in a de-*lightful* manner. This effect is called phosphorescence.

Experiment 89.—Boil a few small pieces of phosphorus in a flask, with some water; sparks will rise in all directions through the liquid, and if at the conclusion of the experiment you throw out the water into the open air on the ground, a splendid flash of light will be shown.

Experiment 90.—Into a test-tube pour half an ounce of olive oil, and add one small piece of phosphorus; heat *gently* over the spirit-lamp. A small quantity of the phosphorus will dissolve, and by rubbing the oil over the hands and face they will become quite luminous. This is a harmless experiment, and the oil can be easily removed by soap and water.

Experiment 91.—*Fire under Water.*—Into a wine-glass put a few grains of chlorate of potass, fill up with cold water, and then add a few pieces of phosphorus. Through a glass tube pour a little sulphuric acid; when this reaches the bottom of the glass, flame will burst out, and thus you will obtain fire under water. This experiment requires caution, as sometimes the phosphorus flies out of the glass, and might injure the eye.

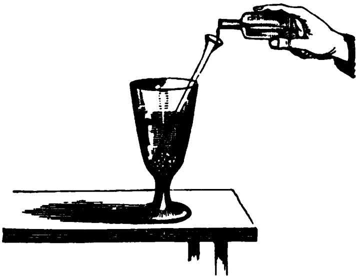


Fig. 40.

Experiment 92.—*Combustion in Oxygen.*—See Experiment 12.

Experiment 93.—*Combustion in Chlorine.*—Proceed as with oxygen, substituting a bottle of chlorine, and a bright light will be given out.

Experiment 94.—*Heat from Water.*—Tie a piece of phosphorus *outside* of a wine-glass, half filled with cold water; pour into the glass some strong sulphuric acid. Sufficient heat will be produced to inflame the phosphorus.

Experiment 95.—*Fire-producing Liquid.*—Into a teaspoonful of sulphide of carbon, contained in a glass-stoppered bottle, put a piece of phosphorus about an inch long, which has been dried by gentle pressure between blotting-paper. In a short time the phosphorus will dissolve. Pour a small portion of the liquid on a sheet of paper, taking care that none runs off; you will presently observe smoke rise from the surface, and immediately after the paper will catch fire. Captain Norton has invented a shell wherein he uses this liquid; on its being fired against the sails of a ship it immediately causes their destruction by burning.

We cannot caution you too strongly with reference to the use of this liquid; it is certainly the most dangerous article yet known. The following anecdote may impress our advice more strongly. After lecturing at Hamilton, the writer was returning to Glasgow, when he observed a dense smoke issue from the carriage in which his assistant was sitting. It seemed that the young man had gone to sleep, and a small portion of this solution of phosphorus had fallen out of a bottle he held in his hand on to his coat, to which he thus set fire. His hand was so severely burnt as to be bad for two months afterwards.

Our advice is, that you do not try the experiment at all for the present, but if you do, never make more of the solution than you require for the moment, and throw any portion left down the sewer, with plenty of cold water.

Lucifer matches are made of phosphorus and sulphur, but their manufacture is very dangerous, and we shall therefore content ourselves by again urging every possible precaution in dealing with this dangerous material. We add, by way of making our remarks of general interest, that it is owing to the presence of phosphorus in animalcules that the sea presents sometimes a luminous appearance at night. The inside of crabs and lobsters, and possibly the glow-worm, owe their luminosity to the same cause.

Experiment 96.—Phosphoretted Hydrogen is procured by putting a piece of phosphide of lime in warm water, or by boiling potass and phosphorus together. Of the two the former is the simplest plan. Beautiful rings of smoke are formed, and as they rise into the air, a slight explosion and light are produced. The annexed diagrams will give you an idea of their appearance and also of the apparatus used.

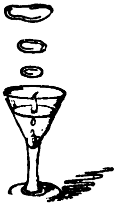


Fig. 41.

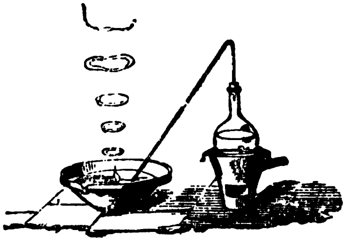


Fig. 42.

SULPHUR.

This substance is so well known, that we shall not waste space in its description, but simply remark that it is chiefly obtained from Sicily and the Lipari Islands. It also abounds in ores of iron and lead called pyrites, and these are employed by sulphuric acid manufacturers as a source of sulphur.

Experiment 97.—*To obtain Crystals of Sulphur.*—Melt some pieces of roll brimstone in an iron ladle, at a very gentle heat. When the whole is melted, remove the ladle from the fire, and allow it to cool until a crust is formed on the top. Make a hole in the crust, and let the melted sulphur inside run out. When cool, the mass in the ladle will present some beautiful crystals of a needle shape, if broken in half.

Experiment 98.—*To make Moulds from Coins.*—Melt some sulphur in a ladle, taking care not to overheat it. Pour this over any coin (except silver, which would be spoiled), first fixing the coin in a paper rim such as a pill-box, to prevent the sulphur running away. The coin should be slightly oiled, to prevent the sulphur adhering to its surface. You can thus copy any medal, and obtain an exact impression from it. These moulds of course give a reverse of the medal, and may be copied by means of plaster of Paris.

Experiment 99.—*To obtain Copies from Plaster of Paris Medallions.*—Proceed as in the last experiment, with the exception that you must moisten the plaster of Paris by water, instead of oiling it. This may be done by placing the plaster mould in a plate of water, and allowing the liquid to soak in, until the moisture rises to the surface of the mould.

Experiment 100.—Place a little brimstone in a Florence flask, and apply a gentle heat to it, by means of the spirit-lamp. The sulphur will sublime, or rise to the top or cool side of the glass, in a yellow-coloured powder, formed of very minute crystals.

Experiment 101.—*To bleach by means of Sulphur.*—Wool, hair, straw, &c., may easily be bleached, and this plan is adopted by wool-scourers, and straw bonnet manufacturers. Take a jar open at both ends, and in the upper part fix the article you wish to bleach, by means of a string tied to a cork; as, for instance, a flower or a piece of straw bonnet, first moistened by water. Then place on a piece of iron or a penny piece, a little sulphur, which must be set on fire, the jar being placed over the fumes. The jar should be slightly raised on one side, to allow a little air to pass in. In a short time the colour of the flower will be completely destroyed by the sulphurous acid thus formed. The arrangement is represented in fig. 44.

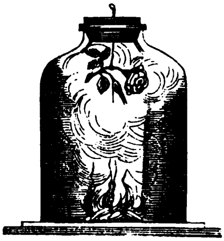


Fig. 44.

Experiment 102. —*To restore the Colour of the Rose.*—After thus bleaching it, dip it into water, containing a very small quantity of sulphuric acid. The colour will speedily be recovered.

Experiment 103.—*Sulphide of Carbon.*—This liquid is obtained by passing sulphur vapour over red-hot charcoal. Pour a little on the back of the hand; its rapid evaporation will produce a sensation of cold.

Experiment 104.—Round a thermometer bulb, wrap a piece of cotton rag. On this pour a little sulphide of carbon, and blow on it. The mercury will rapidly fall, owing to the cold produced.

Experiment 105.—Dissolve some sulphur in sulphide of carbon; on allowing the solution to evaporate, you will obtain crystals of sulphur.

Experiment 106.—*Explosion with Sulphur.*—Rub together in a mortar a little sulphur and chlorate of potass. Smart explosions will be heard. Do not use more of this than will cover the end of a knife, as it is a dangerous mixture in large quantities, and will sometimes explode spontaneously.

Experiment 107.—Mix a little sulphur and chlorate of potass, both in powder, by a knife; place the mixture on an anvil, or on a piece of iron; strike the powder sharply with a hammer, and a loud explosion will follow.

Experiment 108.—*Splendid Blue Fire.*—Mix together in a mortar four ounces of nitre, two ounces of sulphur, and one of sulphuret of antimony, all first separately powdered. Put the mixture into a paper case, or place it on a tile. On lighting it a magnificent light will be given off, which may be seen for many miles. We have employed this light for the purpose of taking photographs at night; and a similar mixture has been adapted to a lamp by Mr. Moule for the same use.

Experiment 109.—*Sulphuretted Hydrogen.*—This gas is known by its fetid smell, and is the cause of our drains and gas-works being so offensive. To obtain it, pour a little hydrochloric (muriatic) acid on some sulphuret of antimony, contained in a glass jar. The gas will soon be given off, and from its offensive smell you will recognise its presence. Take care not to inhale any of it, as it is highly poisonous. Fig. 45 represents a very excellent plan of producing the gas. On the right-hand side we have the vessel containing the materials from which the gas is produced. This passing into an adjacent bottle, gives *a watery solution*, from which the characters of sulphuretted

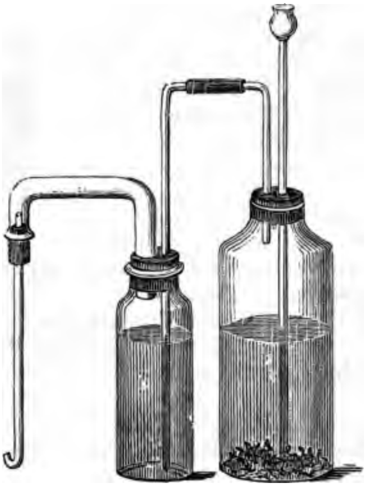


Fig. 45.

hydrogen may be learned. The solution should be kept in well-stoppered glass bottles; and requires to be made fresh when special experiments are to be performed with it.

EXPERIMENT 110.—*To detect Sulphuretted Hydrogen.*—Dissolve a little sugar of lead in water; into this dip some white blotting-paper. On holding a strip of this paper in the jar of gas, or over a foul drain, it will turn black at once.

EXPERIMENT 111.—Into a jar of the gas introduce a little chlorine. The sulphur will be immediately separated, and all smell will vanish. For this reason, chloride of lime may be used to destroy the smell of drains.

EXPERIMENT 112.—*Magic Writing.*—On a piece of paper write anything you please, using as ink a little solution of sugar of lead, and a quill pen. Let it dry, and the writing will be invisible. On moistening it with water, and holding it in a jar of sulphuretted hydrogen gas, or over a drain, the writing will at once be evident, and in black characters. Our young friends may use this simple plan for secret writing. Do not taste the sugar of lead, for, although very sweet, it is a deadly poison.

We conclude our experiments on sulphur by cautioning you that any silver article, either in coin or as a watch, will certainly be spoiled if they come in contact with that substance. It is therefore advisable to remove from the pocket both your money and watch; in fact, our last words shall be "Take care of your pockets, gentlemen," when you experiment with sulphur.

THE METALS.

Our previous experiments have included the gases most commonly met with; and also two or three substances which, although not recognised as familiar objects, are yet employed in many every-day occupations. We must here explain that most of these are active agents in those processes which we daily observe; and because we cannot alter or change them, we call them elements, or unchangeable substances. We shall now pass on to consider others which, by their brilliancy, ductibility, malleability, and other qualities, have acquired the name of metals. Some are very heavy, some very light; or, in other words, you will find that in comparing the bulk of some metals with the same space which water would occupy, their weights differ very much from each other. Platina weighs, for instance, more than twenty *times* the weight of the same bulk of water;

whilst potassium, another metal, is lighter than its own bulk of water.

From these facts we gather the idea of specific gravity, or are enabled to ascertain the relative weight which each metal bears to another, or to a standard such as water, at a temperature of 60°. Iron, for instance, weighs seven times as much as the same bulk of water would do; and if we had a "lump" of water weighing one ounce, a piece of iron of exactly the same size would weigh over seven ounces. We shall, in another section, explain how these relative weights or specific gravities are arrived at.

Metals are found in what we may call a disguised state; that is, we rarely find them in nature in the same form as we use them in daily life. For instance, lead, iron, and copper are generally discovered in connexion with sulphur or charcoal, and intricate processes are required to free them from these substances. The process is called *reduction;* that is, the ore, or natural state of the metal, has to be altered or reduced until the metal itself is really obtained. Sometimes heat is sufficient for the purpose. Mercury, for instance, may be obtained by heating its ore strongly. Iron requires a more complicated process, one which we shall describe under the proper head. Coal, coke, and charcoal, together with limestone, are used in these operations, and there seems to be a pre-existent arrangement in the strata of the earth in many districts which enables us at once to carry out all the processes by a successive arrival at the materials required for the purpose. In Scotland there is a band of minerals which affords coal, limestone, and iron ore in one mine, and thus the proprietors are able to pursue the whole of the mining and other operations within their own works, without the necessity of having recourse to other places or mines which might possess facilities or materials of which they otherwise would have been deficient.

The geological position of the county of Kent is such as to preclude the hope of finding coal necessary for smelting purposes. This, therefore, forms an exception to the instances we have just mentioned.

Our young friends will naturally desire to know what a mine is like, and as we have been in several, we shall endeavour to give them some idea of these remarkable places.

In some parts of America, copper is found in an almost pure state, at the surface of the earth. In Cornwall (England) the miners have to descend to an enormous depth before they reach what is called a *vein* of ore. With respect to lead mines in *Yorkshire,* we have walked, or rather crept, into what are called *levels*, something like a quarter of a mile long, bored into the side of a mountain. Iron ore is found in Lanarkshire, Ayrshire, and other parts of Scotland, in deep mines. The miners, provided with lamps fixed to their caps, work in places of so little height as sometimes to allow only of just the thickness of their bodies: they lay on their left side, and have just room enough to "pick" down the ore from the top of the level in which they work. No person who has never been in a lead or iron mine can have the most remote idea of the hardships which the miners have to endure. Without specifying cases, we are in a position to state that many persons "are put away" annually, without ever being recorded, as *dead*, *lost*, or *crushed.*

We shall give a very general description of the different processes employed for the purpose of obtaining metals from their ores, as we describe each individual of the class. We would just observe that, generally speaking, ores are either oxides, carbonates, or sulphurets of the metals, and, therefore, all that is required to obtain the metals themselves is to drive off the oxygen, charcoal, or sulphur which the ore contains.

With these preliminary remarks we at once proceed to speak of some of the leading members of the metallic family, and, as a matter of course, introduce first to your notice that most valuable of all metals—

GOLD.

This metal is found in small quantities in many parts of Great Britain; in fact, some centuries ago its discovery was very common. Our chief supply is now obtained from the quartz rocks and the sands of Australia and California. Perhaps some of our young friends may have fancied that the yellow substance in coals may be gold, but such is not the fact, that being simple iron pyrites, or iron united with sulphur.

Gold is soft, and easily cut with a penknife, and is separated from the quartz by pounding the stone and washing the earth away by water, in what are termed "cradles." The metal, being heavy, falls to the bottom, and is afterwards taken out and melted into bars. The following experiments can be tried with a little gold-leaf;—take care in purchasing it that you do not get "Dutch gold," which is simply copper, beaten out into thin leaves.

Experiment 113.—*To dissolve Gold.*—Put a piece of gold-leaf into a wine-glass; pour on it some strong nitric acid (aqua-fortis)—the gold will not dissolve; now add a little muriatic acid—the metal will dissolve immediately.

Experiment 114.—*To distinguish Gold from Brass or Copper.*—Rub a chain, or any other article, on a hard stone, which will thus receive a portion of the metal; drop on this some nitric acid: if the mark disappears it shows that no gold is present, as the gold would have remained untouched if the article had contained any.

Experiment 115.—*To gild Steel, &c.*—Into the solution from Experiment 113 pour some ether. This will take up the gold, and by dipping any steel article, say a pair of scissors or a penknife into it, the surface will be at once gilt.

Under the head of electrotyping we shall give full descriptions of the process of electro-gilding and plating.

SILVER.

This well-known metal is found in many parts of the world, and is obtained by a process called amalgamation, from some of its ores. In England silver is frequently obtained from lead ores, some of which contain it in large quantities. The lead is melted in conical-shaped vessels, and the silver being the heaviest of the two, sinks to the lower part. It is then separated from the lead by sawing off the bottom of the cone.

Experiment 116.—*To dissolve Silver.*—Put a little silver-leaf, foil, or wire into nitric acid; the metal will be at once dissolved, and form nitrate of silver. Silver in the form of coin will not do, because, like gold, it is too soft to be used as coin without being alloyed with copper, which is used to harden both metals.

Experiment 117.—*To "silver" Copper.*—Into the solution of silver, to which you have added a little distilled water, place a clean penny piece; it will be at once coated with silver, and if polished, by rubbing with leather, it will retain the appearance for a long time.

Experiment 118.—*To separate Silver from Copper.*—Put a sixpence into nitric acid, and it will quickly dissolve; now add some common salt, and the silver will fall down with the chlorine of the salt in the form of a curdy white powder.

Experiment 119.—Pour off the liquid, and leave the white powder from the last experiment in the sunshine; it will soon turn black. This salt, called chloride of silver, is largely used in photography.

Experiment 120.—*Marking Linen, &c.*—Soak the end of a white pocket handkerchief in a little salt and water: when quite dry write on it your name, using a *quill* pen, dipped into a solution of thirty grains of nitrate of silver to a table-spoonful of distilled water. Expose the writing to the sun's rays, and it will quickly become black, permanently marking the cambric.

EXPERIMENT 121.—*Invisible Writing.*—Take a sheet of note paper, and soak its surface in water containing a little salt; mark the salted side with a pencil, so as to make no mistake in using the wrong surface, hang it up to dry, and by candle-light write a letter to a friend, using the solution of silver and quill pen, as in the last experiment. If you send this by post, first writing in pencil, "Hold me in the sun," your friend will observe no marks, but by obeying your pencil instructions the writing will soon become visible. Don't use the same ink for *directing* your letter, as the postman may have some little difficulty in delivering your epistle, in that case, unless the sun assists him.

EXPERIMENT 122.—*The Silver Tree.*—Put into a small bottle a solution of sixty grains of nitrate of silver, with two wine-glassfuls of distilled water. In this hang a bundle of copper wires made into a kind of brush. In a short time a beautiful precipitation of silver will take place, forming a kind of tree in appearance.

In experimenting with silver solutions, take care not to wet the fingers, as they will soon become black thereby.

PLATINA.

This metal is the heaviest body yet discovered, and presuming that a pint of water weighs one pound, the same quantity of platina would weigh twenty-one pounds. Platina is found in Brazil and Russia, where it is sometimes used as coin.

EXPERIMENT 123.—*To dissolve Platina.*—Proceed as described in the process for gold (Experiment 113). This metal, like gold, is insoluble in most acids.

EXPERIMENT 124.—Hold a piece of platina in a lamp flame; you will find that it conducts heat so slowly as to allow you to place the fingers within an inch of the flame whilst holding the foil.

EXPERIMENT 125.—If you coil some fine platina wire round the wick of a spirit-lamp, so as to form a kind of cone over it, and light the lamp, immediately afterwards blowing out the flame, the wire will become white-hot, and will keep so as long as any spirit remains in the lamp. Fig. 46 illustrates this arrangement.

EXPERIMENT 126.—A plate of clean platina foil, if very thin, may be held in the jet of gas of the hydrogen bottle (see fig. 21); and as the gas escapes it will sometimes set fire to it.

EXPERIMENT 127.—*Spongy Platina.*—Put into a small test-tube some of the solution of platina. (See Experiment 123.) Into this dip a little blotting-paper, and when well soaked, dry and heat it till red-hot, by means of the spirit-lamp. If you now break the tube, and take a piece of the bottom containing the platina in fine powder, and expose it to a jet of hydrogen, as in the last experiment, it will immediately ignite the gas.

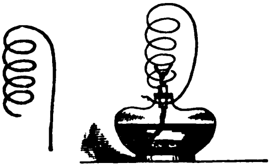


Fig. 46.

EXPERIMENT 128.—*To cover Metals with Platina.*—Proceed as with gold, substituting the solution of platina. (See Experiment 115.)

MERCURY.

This metal differs from every other in the fact of its being always a fluid at ordinary temperatures. It is easily boiled, and may be distilled, like water, in a glass retort. It is obtained from its ores by distillation.

EXPERIMENT 129.—Pour a little quicksilver (its other name) into a Florence flask, apply the heat of the spirit-lamp, and the mercury will condense in the upper part, and run down in globules.

EXPERIMENT 130.—*To filter Mercury.*—Procure an old glove-finger, half fill it with mercury, and twisting the upper end, continue to do so until all the mercury is pressed out. This is a good way of cleansing the metal from dust and dirt. A piece of wash-leather will answer equally as well.

EXPERIMENT 131.—*To "silver" by Mercury.*—Dissolve a little of the metal in some nitric acid diluted with water. Rub some of the solution on any brass or copper articles; they will be instantly coated with mercury, presenting a highly polished appearance. The "silver" solution sold by men in the streets is thus made, and will, if used, most certainly spoil any real silver article.

EXPERIMENT 132.—*Mercury and Silver Coin.*—Drop a four-penny piece into some mercury, or rub it with a little of the last-named solution; on attempting to bend it, the coin will immediately break.

EXPERIMENT 133.—Pursue the same course with another, and put it on a piece of iron which is nearly red-hot. This will drive the mercury off, and restore the silver to its old state.

CAUTION.—Whilst experimenting with mercury, in any form, take care to put aside all money, watches, chains, or rings. For want of attending to this, the author has had the good fortune to put his fingers through the back of a gold watch, which he had carelessly left on a table whereon some mercury had been spilt.

EXPERIMENT 134.—*Magic Solution.*—Dissolve in two separate glasses, containing distilled water, a little bichloride of mercury, or, as it is sometimes called, corrosive sublimate, and some iodide of potassium; then pour a portion of the latter into the mercury solution. A yellow colour will be produced. On adding a little more, the colour will change to a fine red; a still further addition of the iodide of potassium will re-dissolve the red matter, and the liquid will become clear as common water. If some mercury solution be now added, the colour will return; and thus you may alternately have a red-coloured solid, or a transparent liquid, by pursuing the experiment as above. By stirring the liquid with a glass rod the process is hastened.

EXPERIMENT 135.—*Amalgams.*—Any other metal, when united with mercury, is called an amalgam. Thus gold, silver, copper, zinc, &c., may be amalgamated with mercury. On heating the amalgam, the mercury flies off and leaves the metal in its original state.

EXPERIMENT 136.—"*Silvering*" *Glass.*—*Looking Glasses.*——Take a piece of plate or crown glass, and place evenly on it a sheet of tinfoil of the same size; over this, by means of a hare's foot, or a piece of fine flannel, spread some mercury on every part, in an even manner. On this place a sheet of writing paper. Weights must now be laid thereon, which will squeeze off the superfluous mercury. Leave the whole for a day, and the glass will be well silvered. A piece of cardboard should be placed between the paper and the weights.

Mercury is sometimes frozen in the Arctic regions. We shall give directions for freezing it hereafter by artificial means.

COPPER.

This useful metal is widely distributed. It is found in Australia, America, and in different parts of Europe and

Asia. The chief source of copper in this country is Cornwall. The mines in this county often run to a great distance under the sea, and are frequently of great depth. The ore is mostly smelted in South Wales, where extensive works are erected, giving employment to many persons. Copper ores chiefly consist of the metal combined with sulphur and carbonic acid, and they are roasted, that is, burned with coal, to drive off those foreign bodies. We have obtained specimens of copper pyrites—that is, copper combined with sulphur, in Buteshire, and near Campbeltown, in Argyleshire, Scotland. In the former place, a copper mine was worked some years ago. After the ore has been roasted, and the metal, still impure, obtained in small pieces, these are calcined in a suitable furnace; and after various processes, which we must not stop to describe, the nearly pure metal is produced. The metal is sometimes found in an almost pure state; and a mass weighing about one ton is now in the Polytechnic Institution, Regent-street, and contains about 95 per cent. of fine copper.

Many of our young friends have, doubtless, been puzzled in guessing as to what becomes of all the old iron pots and pans. These are sent to the West of England, and cast into water which flows from the copper mines. The acid of the salt of copper contained therein seizes the iron, and leaves the copper in the form of a powder; a process which we will illustrate in our next experiment. The copper is afterwards melted and cast into bars.

Experiment 137.—Into a solution of sulphate of copper, called also blue vitriol, dip a clean piece of iron hoop. It will become coated with copper obtained from the solution at the expense of the iron, which is dissolved away.

Experiment 138.—*To cover Steel Articles with Copper.*—Immerse a penknife, a pair of scissors, or a knitting-needle, in the solution of copper. They will be to all appearance changed into copper. This was one of the tricks of the alchemists, who wished to persuade their dupes that iron was really changed into copper.

The marine store dealers in London are often cheated by these means. Roguish persons coat old iron nails thus with copper, and, as the iron is worth little, whilst the "coppered" nails sell for 10d. per lb., the transaction, though thievish, is highly profitable.

Experiment 139.—Into a solution of copper (Experiment 137) pour some spirits of hartshorn (ammonia). A splendid blue colour is produced. This is used by chemists to fill the bottles they exhibit in their windows.

Experiment 140.—Clean a copper plate, and hold it over the flame of a lamp. It will change colour from red to black, producing the rust or oxide of copper.

Experiment 141.—*To engrave Copper Plates.*—Cover a level copper plate on both sides with wax. (See Experiment 87.) Remove the wax from the surface by means of a penknife, so as to trace any writing, say your name; and dip the plate into some nitric acid. The copper will be completely eaten away, where exposed to the acid; and if you afterwards clean the plate from the wax, and fill the tracing with printer's ink, you can, by pressing on it a damp piece of paper, obtain a complete "copper-plate" engraving. This is the mode adopted by engravers for printing cards, maps, and other matters; and it is largely employed in Manchester and Glasgow for engraving copper rollers used in printing calico for ladies' dresses.

Experiment 142.—The different preparations of copper are all poisonous. Sometimes it is employed to give pickles, fruits, and preserves, a rich green colour. To detect it, put a portion of the suspected article in a wine-glass, with some water. Stir it up for some time, and then add some ammonia. If any copper is present, the water will turn blue. In preserving fruits, by boiling in brass pans, some of the copper is generally dissolved, and this has occasionally been productive of serious results in families. All copper vessels used for boiling, &c., should first be well tinned.

IRON.

We need only name this metal to at once remind you of its great utility; in fact, the chief riches of Britain consist in its iron ores and coal mines. Iron is found universally; it colours the earth on which we walk, and at the same time produces the ruddy glow of health on the cheek. The chief mines in England are those of Staffordshire and neighbouring counties. In Scotland there is an enormous band of ironstone and coal. The chief smelting furnaces in that country are at Coatbridge, Glasgow, Falkirk, and in Ayrshire.

For the purpose of obtaining the metal the ore is smelted with limestone and coal, in furnaces about thirty feet high. These are fed from the top by means of tramways and small wagons. After the fire has been urged by enormous air engines for about twelve hours, the lower part of the furnace is "tapped;" the molten iron then flows into channels called "sows," and "pigs," and "pig iron," is thus produced. The iron in this state is brittle, like glass, but being afterwards "puddled" or worked up in furnaces, and rolled, it comes out in a malleable state, fit for use in daily life.

One of the strangest sights to a traveller, on going to Glasgow by the Caledonian Railway at night, is the reflection of the light of the iron furnaces. For sixty miles the sky wears a lurid glare, and on arriving at Coatbridge, the extensive works of the Messrs. Baird dazzle the eye with the glare of about a dozen of these fire-vomiting arrangements. Fig. 47 will afford some idea of the appearance of an iron-smelting furnace.

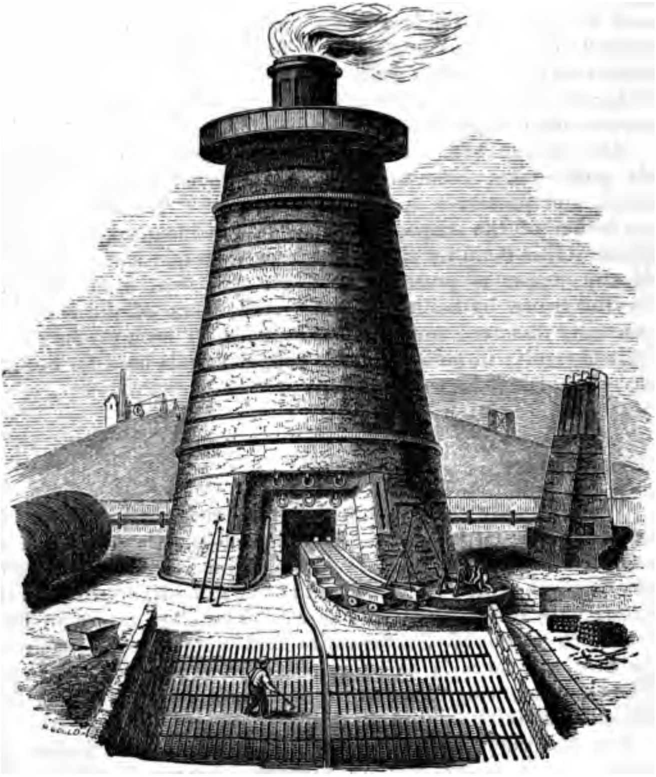


Fig. 47.

We need not attempt to enumerate the various uses of iron.

We shall therefore proceed to experiments which will illustrate its chemical characters.

Experiment 143.—*Ink made from Iron.*—Into a solution of copperas in water pour some tea or tincture of galls. The mixture becomes black, owing to the formation of common ink. Although sulphate of iron is called "copperas," there is not a particle of copper in it.

Experiment 144.—*Copperas from Iron.*—Pour a little sulphuric acid and water on iron nails. Sulphate of iron is thus formed, which may be had in crystals by evaporation. It may be tested with the tea, as in the last experiment, and you will observe the same result. It is made on the large scale by exposing pyrites to the action of air and water.

Experiment 145.—*Prussian Blue from Iron.*—Into some of the solution of nails in sulphuric acid pour a little prussiate of potass. A beautiful blue colour is produced, and is the same as that employed by dyers for dying ladies' dresses of a dark blue. The last-named salt is partly made from blood or the hoofs of cattle, and thus our ladies are indebted for some of their most beautifully coloured ribbons, &c., to old iron hoops and animal refuse.

Experiment 146.—*To obtain Port, Sherry, Milk, Ink, and Champagne from one Bottle.*—Into a clean wine-bottle put one ounce of copperas, a drachm of nitric acid, and a pint of cold boiled water. Now place in four wine-glasses, and one champagne glass, the following articles:—Into number 1, *three* drops of the solution of prussiate of potass (Experiment No. 145); into No. 2, *three* drops of sulpho-cyanic acid (see next Experiment); into No. 3, *six* drops of the same; into No. 4, a few drops of a solution of nitrate of baryta; and into No. 5, a piece, of the size of a pea, of carbonate of ammonia (common

Fig. 48.

1 Blue Ink. 2 Sherry. 3 Port. 4 Milk. 5 Champagne.

smelling salts). Place your glasses on a tray, and ask your friend which he prefers, wine, milk, &c., and by pouring the contents of the wine-bottle into either of the glasses, as arranged in fig. 48, you can satisfy his *eyesight*, but by *no means* let him *taste*.

These effects simply result from the different colours produced by the various substances in the glass, coming in contact with the iron dissolved in the wine-bottle. This experiment will give you some idea of what we mean by *testing*, or the mode of finding out the nature of a substance, by the addition of another to it, and observing the effect which takes place from the mixture.

Until you are an adept at experimenting, you had better have a little mark on each glass by which you may distinguish its contents, lest you should produce sherry instead of milk, &c., by pouring into the wrong glass.

In another part of the work we shall give you instructions for making a bottle that will pour out *real* wine, spirits, &c. The above of course only *appear* like the genuine articles. The numbers we have used correspond with the names mentioned under each glass in our instructions, and indicate the liquids produced.

EXPERIMENT 147.—*To make Sulpho-cyanic Acid, used above.*—Into a test-tube put about equal quantities of prussiate of potass, carbonate of potass, and sulphur, all in fine powder; make these red-hot by means of the spirit-lamp; keep the mixture thus for some time, and then dissolve out by water; filter the solution, and mark it thus, "Sulpho-cyanic solution." It should be kept in a well-corked bottle.

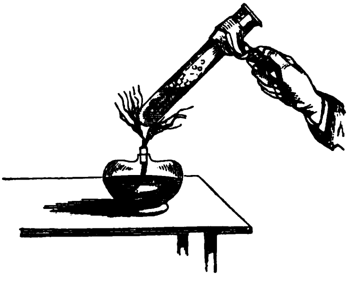


Fig. 49.

To prevent the heat from burning the fingers, wrap a small piece of paper round the tube, and hold it thereby.

EXPERIMENT 148.—Put a little ammonia into some of the copperas solution (Experiment 144); a green powder will be thrown down; expose this to the air, and in a short time it will turn red.

Experiment 149.—*Iron Pyrites.*—Mix in a ladle a little sulphur, with some iron filings and water, so as to form a paste. Sulphuret of iron will be formed. The iron filings heated in a ladle with the sulphur produce the same result.

Experiment 150.—*To melt Iron.*—Heat an iron rod till red-hot, then touch the heated part with a roll of brimstone; the iron will melt away, or rather will combine with the sulphur, and fall down in globules of sulphuret of iron.

Experiment 151.—*Heat from Iron.*—Hammer a large iron nail smartly for some time, and touch a piece of phosphorus with it. The phosphorus will inflame, owing to the heat produced.

Experiment 152.—*Combustion of Iron.* — Sprinkle some iron filings in a gas or candle flame. They will immediately catch fire, burning with fine sparks. For combustion of iron in oxygen, see Experiment 14.

Experiment 153.—*To remove Insects and Weeds from Gravel Walks.*—Water the gravel with a solution of one ounce of copperas in a gallon of water. This will destroy weeds, insects, &c., and give the gravel a red colour. Gravel owes its redness to the presence of iron in the form of rust or oxide.

Steel is made by combining iron with charcoal. This is done by various means, and the iron becomes thereby very elastic. Tempering steel is performed by heating the metal to different temperatures, according to the purpose for which it is required, and is an operation requiring the exercise of skill and judgment.

LEAD.

This metal is found in several parts of Great Britain, and is chiefly obtained from a substance called galena. The ore is roasted with coal, and afterwards smelted in a furnace. The lead is then run off, and cast into bars called "pigs."

Experiment 154.—Melt some lead in a ladle; its surface will soon become covered with a yellow or red substance, which is an oxide of the metal, and is called red-lead, litharge, or minium.

Experiment 155.—Take some of this red-lead and heat it with charcoal. The lead will be reduced. (See Experiment 65.)

Experiment 156.—*The Lead-tree.*—Into a clean bottle put a quarter of an ounce of sugar of lead (called by chemists acetate of lead); to this add half a pint of *distilled* water; hang in the bottle by means of the cork a wire, at the end of which twist two or three pieces of zinc. In a few hours the lead will be reduced in a beautiful vegetable-like form. This makes a nice mantel-piece ornament.

EXPERIMENT 157.—*Chrome Yellow.*—To a little sugar of lead, dissolved in water, add a solution of chromate of potass. Chrome yellow will fall down, a substance much employed by painters as a yellow pigment.

EXPERIMENT 158.—*To manufacture Shot.*—Melt some lead in an iron ladle, and pour it from a height into a pail of cold water. The lead will form into little spheres. Shot is thus made, the lead employed being mixed with a little arsenic, to make it harder.

EXPERIMENT 159.—*Pyrophorus.*—This substance is a powder which takes fire when thrown into the air. To make it, pour some tartaric acid dissolved in water into a solution of sugar of lead. Gather up the white powder thus produced by straining the liquid from it by blotting-paper, and dry it in an oven. The powder should now be put into a long glass tube, closed at the end, and the whole be made red-hot. A strong-smelling vapour will be given off, and when this ceases instantly cork the end of the tube up. When cool, if you break the tube, the powder falls out and catches fire.

EXPERIMENT 160.—Break one of these tubes into a jar of oxygen; a splendid combustion will ensue, and red-lead will line the inside of the vessel.

In another chapter we shall give instructions for the method of handling red-hot lead by the naked hand.

TIN.

This metal is obtained from Cornwall, and is largely used for tinning iron and copper vessels, and by dyers, for the purpose of fixing some colours. It is of a bright white colour, somewhat like silver, and melts at a comparatively low temperature.

EXPERIMENT 161.—*To powder Tin.*—Melt tin in a ladle, and pour it into a box which has some chalk rubbed over the sides. By quickly shaking the box the tin will be reduced to a fine powder.

EXPERIMENT 162.—*To tin Iron or Copper.*—Clean the piece of metal perfectly, and rub it over with a solution of sal-ammoniac. Having a ladle of ready melted tin, throw on its surface a piece of tallow, and dip in the metal you wish to cover. *It will appear* beautifully covered with tin on its removal from

the
var ladle. Iron plates are thus tinned, and are used for making
ious domestic articles.

Experiment 163.—Hold a piece of tinfoil in the lamp-flame. It will speedily melt, and small portions will fall down, burning with a fine white flame.

Experiment 164.—*To set fire to Tinfoil.*—Put some crystals of nitrate of copper on a sheet of tinfoil, sprinkle water on their surface, and roll the foil up quickly. The whole will speedily catch fire.

Pewter is an alloy of tin. Tin in the shape of foil is much used for the purpose of making looking-glasses. (See Experiment 136.)

ZINC.

Zinc is obtained by smelting its ore, called calamine. When melted into cakes, it is sold under the name of spelter. This metal has lately come much into use for a great variety of purposes, and we here present a few experiments with it.

Experiment 165.—Melt some zinc in a ladle, and turn the contents into the fire. If you now urge the fire by a pair of bellows, the zinc will burn with a splendid blue flame.

Experiment 166.—Melt some saltpetre in a ladle, and throw in some shavings of zinc ; a splendid combustion will take place, forming a very brilliant experiment, and oxide of zinc will fly off as a white powder.

Experiment 167.—Place on one side of the tongue a half-crown, and on the other a small piece of zinc. Until the two metals touch you will perceive no sensation. On bringing their outer edges together, however, a metallic taste will be at once produced. This little arrangement forms a galvanic battery, and electricity is set free by it.

Experiment 168.—*Cure for Toothache.*—Have a piece of silver and zinc soldered together in the annexed shape ; by applying this little arrangement on each side of the gum affected, toothache is often relieved. Fig. 50 represents one of these simple arrangements, and its actual size.

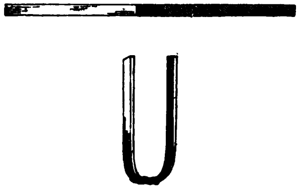


Fig. 50.

Zinc is now largely employed for making galvanic batteries, used in working the electric telegraphs, a subject to which we shall refer at large, under the head of Voltaic Electricity and Electro-Magnetism.

COBALT.

Cobalt has a very limited application. It is used as a colouring matter in the manufacture of paper, in staining glass, and as a pigment.

Experiment 169.—*To produce Pictures which change Colour by warming them.*—Instead of the usual water-colours employ solutions of chloride, and acetate of cobalt, and chloride of copper. These chemicals may be obtained at any operative chemist's at a slight cost. A picture, when cold, if painted with these, may be arranged as a winter scene; but on bringing it near the fire the heat has such an effect on the different substances employed, as to turn "winter" into "summer" almost instantaneously. Do not over-heat these pictures, as by so doing you may prevent a successful repetition of the changes they present.

Experiment 170.—Write your name on a card or a piece of paper with the chloride of cobalt, by means of a quill pen. On warming the card, the writing will change from a pink to a blue colour.

In the foregoing experiments on metals we have confined your attention entirely to those best known and most used in daily life. We need scarcely tell you that the chemist recognises many other bodies as metals, to which we have not alluded. As, however, we could not suggest any very interesting experiments with them, we shall now conclude our remarks on these bodies, by just giving a short description of the chief characters and uses of the remaining members of the family.

With respect to potassium and sodium, we shall offer some experiments with them under the head of alkalies, and shall adopt the same course with those metals which form the base of the different earths, such as magnesium, calcium, aluminium, &c.

Antimony, bismuth, and arsenic are used in the arts and in medicine; the former employed in manufacturing printing types. As arsenic is a most deadly poison, we refrain from offering any experiments with it. The metal nickel is used in making Britannia metal, or what is sometimes called German silver.

Some metals, such as iridium, osmium, &c., have somewhat similar characters to those of platina, with which, in fact, they are generally found in nature.

Manganese is chiefly employed in the manufacture of bleaching-powder, to produce chlorine, and to give a colour which is *employed in* calico printing.

When two or more metals are melted together, they form an alloy. Thus gold and silver coin are alloys, being mixtures of those metals with copper. Pewter and brass are instances of the same kind.

Almost all the metals will combine with and dissolve mercury. This product is called an amalgam. The metal may generally be recovered by heating the amalgam, and so driving the mercury off.

Having thus endeavoured to give you experiments which will afford a general idea of the individual character of the metals, we shall now pass on to consider an entirely different class of substances, which will afford us many interesting matters, both for experiment and observation.

ACIDS AND SALTS.

We have hitherto restricted our experiments to substances called *elements*. By this term we mean simply, that out of such we can get nothing but themselves. For instance, we may make every possible attempt in the present state of chemical knowledge to extract anything from gold different to itself, and we shall fail. For this reason we call gold an element. But if we try the same course with marble, the result will be very different, for from marble we can get both lime and charcoal, in the shape of carbonic acid. (See Experiment 42.) Marble we therefore call a compound; and it is with this sort of bodies we are now about to deal.

Everybody knows what an acid is; common vinegar is a specimen of the class: but everybody does *not* know what a chemist means by the word *salt*, but we will endeavour to explain it. Common salt and Epsom salts belong to this class of substances; and in general, when we say that anything is a *salt*, we simply mean that something has been united to an acid. If you pour tartaric acid on carbonate of soda, you form the salt called tartrate of soda; or if vinegar is poured on iron, you have acetate of iron. Now, the name of the salt is doubly derived, part from the substance added to, and part from the acid. Thus, in the case of the tartrate of soda, the word *tartrate*, as you perceive, is derived from the tartaric acid; the soda is called the *base* of the salt, and thus we have sulphates from bases with sulphuric acid, nitrates from bases with nitric acid, as sulphate of magnesia and nitrate of potass, which in common language are called Epsom salts and nitre or saltpetre. You will perceive at once the great advantage of these titles to salts, because you can learn by their names what they are composed of. Who could guess what Glauber's salts are made of? but using their chemical name, sulphate of soda, we have no difficulty in arriving at such knowledge.

Having thus endeavoured to explain the meaning of these terms, we proceed to give you a variety of interesting experiments.

SULPHURIC ACID.

This acid is of the utmost importance in daily life; it is largely used in bleaching and various manufactures. Its manufacture is carried on in many of our large towns, but especially in Manchester and Glasgow. By burning sulphur, and receiving its vapour in large leaden chambers, through which steam and nitric acid are passing at the same time, the acid is generally produced on the large scale.

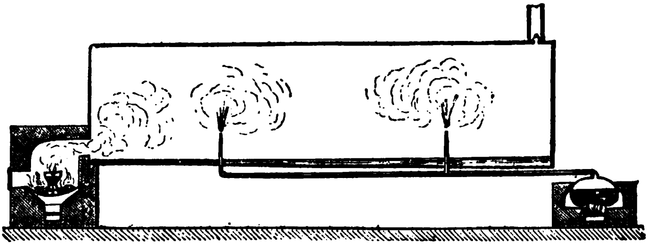


Fig. 51.

Our diagram, fig. 51, represents a section of a sulphuric acid chamber. On the left is the furnace supplying the vapour of sulphur and nitric acid; in the centre, we have the large leaden chambers in which the two vapours combine together with steam produced from a boiler represented on the right of the diagram. The construction of these arrangements varies very much; but our young friends may gain an adequate idea of the process by examining the above sectional plan.

Sulphuric acid thus produced and concentrated is a powerful poison: it has the appearance of an oil, being thick; hence it is often called oil of vitriol.

EXPERIMENT 171.—*Great Heat produced by Sulphuric Acid.* —*Pour some strong* acid into a basin containing water. Great heat will be produced, and if the experiment is conducted in a glass vessel its fracture is almost sure to happen.

Experiment 172.—*Two Pints do not make one Quart.*—Into a long test-tube pour equal quantities, by measure, of cold water and strong sulphuric acid. You will find that they will not occupy twice their separate bulk, but considerably less, owing to the water being condensed into less space.

Experiment 173.—Wet some blotting-paper, and when it no longer drips, hang it inside a bottle containing four ounces of strong sulphuric acid, so as *not* to touch the acid; in a short time it will be quite dried, owing to the attraction which this acid has for water; cover the top of the bottle with a cork, so as to keep the air out.

Experiment 174.—*This Acid is heavier than Water.*—Weigh two glasses in the separate scale-pans against each other, so as to be exactly balanced. Now pour into one an ounce measure of water, and into the other one ounce measure of sulphuric acid. You will find that the water side will require nearly an ounce weight to restore the balance; sulphuric acid weighing nearly double that of its bulk of water.

By the term specific gravity we have already explained that we mean the relation of bulk and weight to one fixed standard; and thus taking water as the standard, the specific gravity of sulphuric acid is as eighteen to ten. In other words, a quantity of acid, equal in bulk to one of water weighing ten pounds, would weigh over eighteen pounds.

Experiment 175.—*To turn Blotting-Paper into Vegetable Parchment.*—Make a mixture of about equal parts of sulphuric acid and water; dip into this, when cold, a piece of blotting-paper, and immediately remove it into a glass containing ammonia; wash afterwards with water, and on drying, the paper will be found completely changed. It will be now quite strong, and resemble parchment in many respects. This paper has been used for bank notes, deeds, and other purposes, and is the subject of a patent. We cannot give the exact proportions of acid and water.

Experiment 176.—*A Liquid which will instantly turn into a Solid.*—Dissolve in boiling water as much Glauber's salts (sulphate of soda) as the water will take up. This is best done in a flask. Cork the flask, and place it in some situation where it will not be disturbed till cool. Suddenly shake it up, and it will become immediately solid. On warming it again it will become liquid, and thus serve any number of times for your magical experiment. The effect is owing to the sudden crystallization of the salt.

Experiment 177.—*Two Solids which will turn into a Semi-Liquid.* — Pound together in a mortar some Epsom salts (sulphate of magnesia) and sugar of lead; the whole will become quite wet, through the chemical changes which occur.

Experiment 178.—Into a large quantity of water, say a pint, drop a very little sulphuric acid, and add a solution of nitrate of baryta; a white powder of sulphate of baryta will fall down. You may thus detect sulphuric acid in vinegar, with which the latter is often adulterated.

Experiment 179.—Pour a little sulphuric acid on wood, bread, potatoes, starch, &c. Its great attraction for water will set their charcoal free. (See Experiment 52.)

Sulphuric acid is largely employed in the manufacturing districts for bleaching purposes. It has lately been much used to dissolve bones when they are intended for a manure. Blacking manufacturers employ it, as many pairs of boots and shoes testify by falling into holes when too much acid has been added to the blacking. It is used in medicine as a tonic. It is manufactured in immense quantities at Newcastle, St. Helens, and in Glasgow, where Messrs. Tennants have extensive lead chambers. This firm and many others distil the acid in large platina stills, for the purpose of separating from it a little lead, &c., which is dissolved during the process of the manufacture.

NITRIC ACID AND NITRATES—GUNPOWDER, GUN-COTTON, ETC.

Nitric acid is obtained from nitre or saltpetre, and is used by refiners, and generally in the metal trade, for cleansing and polishing. Engravers also use it, as we have already mentioned. (See Experiment 141.) It gives a yellow colour to wool, and we must caution you as to its use, as the fingers will acquire a yellow tint, and woollen clothes are spoilt, if they come in contact with this acid. Be careful also not to inhale the fumes, as they are very dangerous to the lungs. It is called in commerce aquafortis, such, however, being generally a weak kind of the acid.

Experiment 180.—*To prepare Nitric Acid.*—Put a little nitre, with some water, into a retort, and add some sulphuric acid; apply a gentle heat, and insert the stem of the retort loosely in a Florence flask. The liquid that distils over is the nitric acid. The flask should be kept cool by a wet cloth.

Fig. 52 gives an idea of a mode of producing the acid on a small scale. The retort is heated by a charcoal furnace, and the receiver kept cool by water flowing on to a piece of cloth.

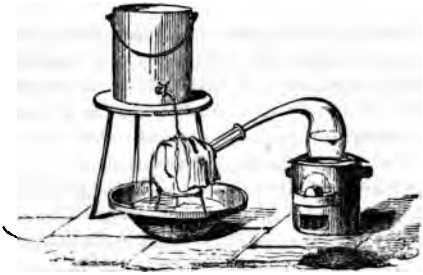


Fig. 52.

The plan is one generally adopted in laboratories, but our young friends will succeed just as well by the simple mode we have named. The product left in the retort is sulphate of potass. This should be washed out when cool with plenty of cold water.

Experiment 181.—*To make a Colourless Gas turn Red.*—Into a retort, or flask, with a glass bent tube, put some copper wire, and pour on to it some nitric acid diluted with water;

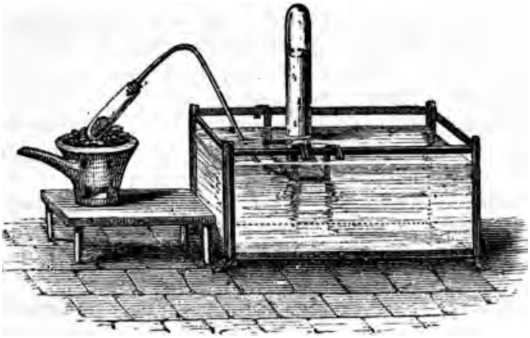


Fig. 53.

dip the stem of the retort or tube into water in the pneumatic trough, and receive the gas which passes over into a jar in the usual way. (See Experiment 8.) When the water is quite displaced by the gas, the jar will appear colourless, but on lifting it from the water the gas in the jar will assume a blood-red colour, owing to its seizing the oxygen contained in the air, and nitrous acid gas is produced. Sometimes a gentle heat is required to assist the process, for which apply the spirit-lamp.

Fig. 53 illustrates the plan, with the exception that a small charcoal furnace is introduced in place of a spirit-lamp.

Nitric acid is composed of one part of nitrogen to five parts of oxygen, and owing to its containing so much of the latter gas it produces remarkable effects on some bodies containing charcoal, one of which we will now illustrate.

EXPERIMENT 182.—*Gun Cotton.*—This extraordinary substance was at first expected to become a substitute for gunpowder, but the rapidity of its explosion renders it dangerous for use in guns. The Austrians are said to have lately availed themselves of it for that purpose (July 1860). It is used for the manufacture of collodion, and by miners in blasting. The following directions, if carefully attended to, will ensure success in its preparation :—

To prepare Gun Cotton.—Take a handful of jewellers' cotton, place it in a tall glass jar, and pour on it two ounces of the strongest nitric acid, previously mixed with half the weight of sulphuric acid. These must be allowed to cool before using them. Press the cotton down with a glass rod in the acid mixture, and leave all together for about ten minutes ; remove the cotton by means of the glass rod, and wash it under a stream of cold water until every vestige of acid is washed away ; the cotton may then be opened out by the hands, and exposed to the sun to dry. Do not use artificial heat, as you may run the risk of an accident by explosion.

EXPERIMENT 183.—*Experiments with Gun Cotton.*—Place a small piece on the hand, and apply a light. The cotton will burn off rapidly without doing injury to the hand.

EXPERIMENT 184.—Tie a piece in a long narrow strip of paper, and fold it in the usual shape of a cracker; it will explode with a loud noise like gunpowder, on being set fire to.

EXPERIMENT 185.—A very small piece may be forced inside a strong key, and rammed in by a little paper ; on heating the key over a candle-flame, it will give a loud report.

EXPERIMENT 186.—Into a small cartridge place a little gun-cotton, and in another some gunpowder loosely ; on lighting both, you will observe how much more rapid the combustion of the cotton is than that of the gunpowder.

EXPERIMENT 187.—*Collodion.*—Pour some ether, to which a little spirits of wine has been added, on some gun-cotton. The latter will dissolve, and form what is called collodion. This may be employed for covering cuts or injuries to the hands, forming, as it does, an excellent "court plaister." Its chief use is in photography.

Experiment 188.—*Gunpowder.*—Our young friends will, we presume, think this subject one of the most interesting applications of chemistry. We will, therefore, give some account of its manufacture.

Nitre, sulphur, and charcoal are the articles employed in manufacturing gunpowder. They should all be very pure, and in a fine powder. The proportions employed vary, just according to the purpose for which the powder is to be used, but for an experiment the following quantities will suffice, viz. :—

Powdered nitre..................	one ounce and a quarter.
,, sulphur...............	one quarter of an ounce.
,, charcoal	one quarter of an ounce.

Pound the charcoal and sulphur together in a mortar, until they are well mixed. Then add the nitre, with a little water, so as to make the whole into a stiff paste. Take the paste out with a knife, and knead it on the back of a plate. Leave it to dry, and then convert it into a powder by gently pounding it in a dry mortar. This, on being sifted, will form a good imitation of meal-powder, providing you have mixed the ingredients completely.

We next append recipes for making coloured fires; as, however, some of these are liable to catch fire spontaneously, they should never be made in large quantities.

Experiment 189.—*Blue Fire.*—Take four ounces of nitre; two ounces of sulphur; and one ounce of sulphuret of antimony. These, in powder, should be well mixed in a mortar. There is no risk in making, or keeping these ingredients together.

Experiment 190.—Red fire owes its colour to nitrate of strontian, and in this and the remaining mixture, where we employ chlorate of potass and sulphur, you must on no account mix them in a mortar, as a most dangerous explosion may ensue. The best plan is to pound each article separately, and then mix them in a plate by means of a piece of wood.

Red Fire.—

Chlorate of potass	one ounce.
Sulphur........................	one ounce and a half.
Sulphuret of antimony ...	one ounce.
Nitrate of strontian	six ounces.
To which may be added of charcoal powder ...	quarter of an ounce.

Or another and safe recipe is—

Charcoal powder	half an ounce.
Nitre	one ounce.
Sulphur	one ounce.
Nitrate of strontian	four ounces.

This mixture may be pounded in a mortar, owing to the absence of chlorate of potass.

EXPERIMENT 191.—*Green Fire.*—

Chlorate of potass	one ounce.
Sulphur	one ounce.
Charcoal powder	quarter of an ounce.
Sulphuret of antimony	one ounce.
Nitrate of barytes	six ounces.

Or—

Sulphur	two ounces.
Sulphuret of antimony	one ounce.
Nitrate of barytes	four ounces.
Boracic acid	four ounces.

EXPERIMENT 192.—*White Fire.*—

Sulphur, one part
Charcoal, one part
Nitre, four parts
Mixed in quantities, produce a white flame.

Many varieties of coloured fires are produced by employing sulphur, sulphuret of antimony, charcoal, and chlorate of potass, combined with various salts. The foregoing will enable our young friends to at least vary their scientific studies by an admixture of science in sport; and, as all work and no play has an evil effect on the young mind, we hope the above recipes may "lighten" our readers' assiduity and attention.

A variety of coloured fires may be made by dissolving various salts in spirits of wine. These are perfectly safe, and may be tried in a parlour without the least risk.

EXPERIMENT 193.—*Red Fire.*—Pour into a plate some spirits of wine, in which you have first dissolved some nitrate of strontian. This will give a red flame on being ignited.

EXPERIMENT 194.—Direct the oxygen jet (see Experiment 16) on this flame whilst burning; the light will be greatly increased.

EXPERIMENT 195.—*Green Fire.*—Dissolve as much chloride of barium, or nitrate of barytes, in spirits of wine as will be taken up. This will produce a green flame on being ignited. To increase the light, proceed as in the last experiment with the oxygen gas jet.

EXPERIMENT 196.—*Yellow Fire, and "the Manufacture of Ghosts."*—Dissolve some common salt in spirits of wine, and in *a dark* room set fire to the solution. A most ghastly colour will be observed on every face present, and by clothing yourself with a white sheet, you may personate a ghost with great effect.

Experiment 197.—To judge of the effect of this flame on colour, dip a lump of tow into the solution, and set fire to it, holding it some distance off, by means of a stick. The colours of ladies' dresses and ribbons will be entirely changed. Bright red will appear of a slate colour, and light pinks, yellows, and blues will all appear alike.

Experiment 198. — Other nitrates than those we have described are produced by pouring nitric acid on the metals, diluted generally with a little water. Thus, with silver, nitrate of silver is produced; with copper, nitrate of copper, and so on. These may be obtained in crystals by exposing the solutions to heat, or by leaving them to gradual evaporation in the air.

The chief uses of nitric acid we have already named. The nitrates, such as nitre, are mostly employed for the manufacture of gunpowder; the nitrates of barytes and strontian for fire-work making; and nitrate of silver is used in medicine and also by photographers, as will be explained under the head "Photography."

HYDROCHLORIC OR MURIATIC ACID.—CHLORIDES, COMMON SALT, AND FREEZING MIXTURES.

Muriatic acid, or, as it is now called, hydrochloric acid, is obtained from common salt. Its fumes are very penetrating, and must therefore be avoided. Its original state is that of a gas, but it is found in commerce, dissolved in water, and often of a yellow colour, owing to the presence of a little iron. It is composed of chlorine and hydrogen gases.

Experiment 199.—*To prepare Muriatic Acid Gas.*—Into a tall, strong, and narrow jar, put equal measures of chlorine and hydrogen gases. Expose them to sunshine, and they will unite, with an explosion, forming muriatic acid. This is a dangerous experiment, and must only be tried on a small scale. A tube one inch wide, and very thick, and about six inches long, will answer the purpose. We have here an instance of an acid being produced without the aid of oxygen gas. Test the gas by moist litmus paper, and the latter will turn red.

Experiment 200.—*To prepare the Liquid Acid.*—Use the same apparatus as that described for nitric acid; but put a little water into the Florence flask, into which the retort or tube may just dip. The retort should be partly filled with a little common salt and water. On pouring some sulphuric acid on these and applying heat, muriatic acid gas will be given off, and will be condensed by the water in the flask forming the liquid acid. The receiving-flask should be kept quite cool by means of water, or, if convenient, by a little ice.

Fig. 54 represents another method of making the acid, where, instead of a flask to receive the gas, a bottle with three necks is employed, into one of which the tube from the retort passes. The centre tube is a kind of safety-valve, and the outside one allows air to pass from the retort. The bottle contains water for absorbing the gas.

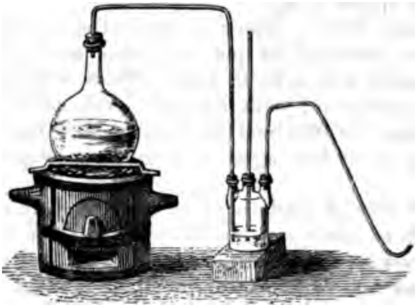


Fig. 54.

Experiment 201.—Dip into the water in the flask a small piece of litmus paper. On touching the acid water it will immediately become red. The acid may be perceived by simply tasting the water, which will be very sour to the palate.

Experiment 202.—*To make a Solid from two Gases.*—Let the gas produced in Experiment 200 run into a glass bottle. When the smell of the gas is perceived, pour into the bottle a little ammonia. Dense white fumes arise, owing to the production of sal-ammoniac.

Experiment 203.—Fill a bottle with muriatic acid gas, and moisten the inside of a Florence flask with ammonia. Now introduce the neck of the flask inside the bottle of gas, and solid sal-ammoniac will be at once formed. Fig. 55 represents the plan described.

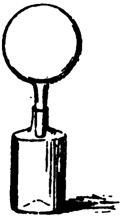


Fig. 55.

Experiment 204.—Another way of trying the experiment is by putting a little of the liquid acid *and ammonia* in two separate wine-glasses. Little or no effect will be shown until they are brought together, when dense fumes of sal-ammoniac will at once be produced.

The salts produced by hydrochloric acid with a base are called *chlorides*. They used to be named *muriates*, but owing to a change in the chemical opinions respecting chlorine, the former term is always used now. An instance of these is common salt or *chloride* of sodium. We shall mention a few experiments with these bodies.

Experiment 205.—*Colourless Ink turned Blue.*—Write on a sheet of paper, by a quill pen, with a very weak solution of chloride of copper. Hold the writing over a cup containing some ammonia, and blue writing will at once appear. (See Experiment 139.)

Experiment 206.—*To make Chloride of Copper.*—Heat a strip of copper, and when completely black, break off the black scales. On these pour a little muriatic acid, and the chloride of copper will be produced.

Experiment 207.—*Freezing Mixtures.*—It is a very common practice to throw salt on snow, for the purpose of melting it. This produces great cold, as you may see by introducing a thermometer into the mixture, when the mercury will fall below 32°, or freezing point.

Experiment 208.—*To freeze Wine.*—Mix together equal parts of sal-ammoniac and nitre, both in a fine powder. Place them in a tea-cup, and in the tea-cup a thin test-tube, half filled with sherry wine. If water is now poured on the salts, and the mixture stirred up by the test-tube, the wine it contains will be frozen.

Experiment 209.—*To freeze Mercury.*—Mix equal weights of snow or pounded ice and chloride of calcium; the cold produced will be sufficient to freeze mercury, which should be placed in a test-tube in the mixture.

Experiment 210.—*Chloride of Calcium.*—To prepare this, dissolve some marble in muriatic acid, and heat the mixture in a test-tube till quite dry. It must then be fused in a crucible, and kept, when cool, in a glass-stoppered bottle. It is better, however, to purchase this article from the operative chemists, who always keep it in stock. As it soon attracts moisture from the air, it should never be exposed thereto, and only just as much as you require is to be removed from the bottle for use.

The chief of the chlorides is common salt, which is obtained from sea water, from mines, and other sources. The chlorides of mercury are used in medicine, the chloride of silver in photography, and several of the others, although to a very limited extent, in the arts and commerce.

CHLORIC ACID AND CHLORATES.

The chief salt formed by chloric acid is that called chlorate of potass, which we have so often mentioned that it will be unnecessary to introduce any further experiments with it. We shall content ourselves, therefore, under this head, by repeating our admonitory remarks with reference to the use of chlorates. They form with many substances, explosive compounds, and generally our young friends will do well to confine themselves to the experiments which we have given, all of which can be performed with safety, and to omit trying many others we might have introduced, but which we have omitted for the purpose of preventing the occurrence of accidents.

VEGETABLE ACIDS.—ACETIC ACID, VINEGAR, TARTARIC ACID, CITRIC ACID, ACIDS OF APPLES, LEMONS, ETC.

The acids of which we have been speaking have often been termed *mineral acids*, because they are chiefly obtained from mineral sources. But there are others obtained from vegetables, &c., and our youngest readers will not fail to remember that when unripe fruit is eaten, a sour taste is perceived. This is owing to the presence of an acid, and of such acids we shall now speak. They are nearly all composed of oxygen, hydrogen, and carbon.

EXPERIMENT 211.—*To detect Acids in Fruit, &c.*—Make a strong solution of litmus or archil in hot water; in this soak some strips of white blotting-paper, about an inch wide and six inches long. These will form a test for acids, the blue colour turning red in their presence. The slips may be carefully dried and stitched into a book form, and kept in a place free from acid vapours. We call these litmus papers.

EXPERIMENT 212.—Press a little of the juice of a sour apple, or of a piece of rhubarb, on a piece of litmus paper; the blue will turn red, owing to the presence of an acid. The acid from apples is called malic acid, from the Latin word *malum*, an apple.

We would suggest to our young friends a very interesting application of these experiments. By taking a small book of litmus paper with you in your field-walks, you may, by pressing the leaves of different plants, extract their juices, and observe whether such have an acid action on the paper.

Experiment 213.—*To obtain an Acid from Burning Wood.* —Into a test-tube put a few chips of wood, and at the mouth of the tube a small piece of litmus paper, slightly moistened. On heating the wood till it chars, a quantity of acid vapour will be given off; and on reaching the test-paper, will turn it to a red colour. This acid is common vinegar in an impure state, and is called pyroligneous acid.

Experiment 214.—*Vinegar from Malt Liquors.*—Allow common ale to be exposed to the air for a few days; all its sweetness will be lost, and eventually an acid produced. This is the mode of obtaining vinegar generally adopted by the manufacturers. Vinegar in the pure colourless state and distilled, is called by chemists acetic acid.

Experiment 215.—*Acetic Acid from Sugar of Lead.*—Pour a little dilute sulphuric acid into a solution of acetate or sugar of lead. The acetic acid will be at once perceived by its strong smell.

Experiment 216.—*The Vinegar Plant.*—A very common mode of making vinegar from sugar, treacle, and water, has lately come into use, by placing in a jar a fungus-like plant called the vinegar plant. It seems to act by causing the fermentation of the sugar, &c., and a change of the sweet or saccharine matter into acetic acid. A quarter of a pound of the commonest brown sugar and a little treacle, with a quart of water, should be put into a stone jar. In this place a "vinegar plant," and in three or four weeks excellent vinegar is produced.

Vinegar from Wine.—Leave wine exposed to the air at a temperature of about 65 deg., and acetic acid will speedily be formed. The taste of vinegar, independent of its acidity, is due to the vegetable matter dissolved therein.

TARTARIC ACID.

Experiment 217.—Tartaric acid is found in the juice of grapes. Its presence is easily shown by adding a little carbonate of potass to a solution of the acid in a glass. On touching the sides of the glass with a piece of broken glass tube, minute crystals of cream of tartar, bitartrate of potass, are deposited on the parts which have been rubbed with the glass tube. It is found in many sorts of wines.

CITRIC ACID.—OXALIC ACID.

Experiment 218.—*Citric Acid.*—This acid is obtained from lemons, by adding some powdered chalk, and subsequently a little sulphuric acid and water. The citric acid is found in the liquid, the sulphate of lime falling down in the shape of a white powder.

Experiment 219.—*To print White Spots on Black Calico.*—Dye a piece of calico black, by boiling it separately in a little logwood and water and a solution of copperas. When dry, press on the surface a piece of wood which has been wetted by a strong solution of tartaric or citric acid, and the colour will be discharged, leaving a white mark.

Experiment 220.—*To take Ink Stains from Books, &c.*—Moisten the stain with a solution of tartaric or citric acid. The ink mark will be speedily effaced by the iron being dissolved away.

Experiment 221.—*Oxalic Acid.*—This acid is found in rhubarb, sorrel, &c., and is a deadly poison. In case of poisoning by this acid, a little chalk, or the whitening from the ceiling, should be mixed in water and immediately swallowed. This is the best antidote for oxalic acid as a poison.

Experiment 222.—*To take out Paint Stains.*—Dissolve a little salts of sorrel, oxalate of potass, in water, and apply the solution to the stain. It will be speedily removed. Ink stains may also be taken out thus.

Experiment 223. — To prevent mistakes between Epsom salts and oxalic acid, heat the substance suspected on a hot shovel. If it completely evaporates, it is oxalic acid; if a solid white residue is formed, oxalic acid is not present, and the only other substance likely to be there is sulphate of zinc or white vitriol, which is easily known by its intensely metallic taste.

Experiment 224.—*Oxalic Acid from Sugar.*—It is remarkable that the sweetest substance we have in use in daily life can easily be converted into a deadly poisonous acid. For this purpose, boil some loaf sugar with four times its weight of nitric acid, to which a little water has been added : oxalic acid is thus formed, and will be deposited in crystals.

There are a variety of other acids obtained from vegetables, such as the malic from apples ; camphoric from camphor ; gallic from galls ; tannic from oak bark, chesnuts, &c. ; but as we cannot suggest experiments of any special interest, we shall introduce them casually amongst our miscellaneous chemical *experiments.*

ALKALIES.—POTASS, SODA, AMMONIA.

It is usual in systematic chemical works to describe these substances under the heads of metals; we adopt a different course, inasmuch as our object is not so much an accurate scientific classification, as to impress leading facts on the minds of our young friends.

Alkalies are much used in daily life; to their action on oils we are indebted for our soaps and other detergent materials. We shall commence our experiments with potass, or pearl-ash as it is often called in commerce.

Experiment 225.—*To obtain Potass.*—On the ashes of burnt wood pour some water; then evaporate until a solid is produced: this is the common potass. To obtain potass in a purer state, a little lime should be added, and the liquor will then contain, after filtering, nearly pure potass.

Experiment 226.—*Potassium obtained from Potass.*—Sir Humphrey Davy was the first to discover that potass was the oxide of a metal. By placing a piece of the metal potassium in the open air it will attract oxygen gas, and a white powder, which is pure potass, will be produced. We have already given experiments with this metal. (See Experiments 5 and 6.)

Experiment 227.—*To detect an Alkali.*—We described, under the head of "Acids" (see Experiment 211), how to find a test for them. For detecting alkalies dip a piece of litmus paper into an alkaline solution after the paper has been reddened by an acid, and its blue colour will be immediately restored.

Experiment 228.—*Another Test.*—Make a strong infusion of turmeric, by putting some of its powder into boiling water; soak some strips of white blotting-paper therein until of a rich yellow colour. These dried form a test for alkalies.

Experiment 229.—Into a solution of potass, soda, or ammonia, dip a piece of turmeric paper; with the two former it will turn to a deep brown; with the latter the colour will at last fade to the original yellow, owing to the evaporation of the ammonia from its surface, although its first effect is equal to that of the other alkalies.

Experiment 230.—*Soft Soap.*—Boil together the solution made by Experiment 225 with any animal oil: soft soap will be produced.

SODA.

Experiment 231.—Soda is obtained from sea plants by burning them, but commercially it is prepared on the large scale from common salt. Extensive manufactories of soda are found at Warrington, Newcastle, and Glasgow. In the latter city the Messrs. Tennant have a very large manufactory at St. Rollox, devoted to the production of soda and bleaching-powder. In this establishment common salt is decomposed by sulphuric acid, the muriatic acid gas being carried off by a chimney 420 feet high. The sulphate of soda thus formed is decomposed by heating it with coal, &c., and the soda is dissolved out and crystallized; soda is an oxide of the metal sodium, and may be obtained by the metal being exposed to the air, when by union with oxygen a white powder, which is pure soda, is formed.

Experiment 232.—*Soap.*—Boil together a solution of soda and tallow. After a little time the two will combine, and form solid soap. The soap manufacturers often employ resin and animal fats of different kinds, for the purpose of producing soap of an inferior sort at a lower price.

Experiment 233.—*To dissolve Animal Matter.*—Boil a piece of raw meat in a strong solution of soda; the meat will be completely dissolved. This explains the action of the alkalies on the skin, which they speedily destroy if placed in contact with it. Laundry-women's hands are thus very often sore, from the action of the alkalies in soap and washing-powders.

AMMONIA.

This is sometimes called the volatile alkali, owing to its being a gaseous body. It is obtained from a variety of sources, but chiefly from animal substances. It is produced during the manufacture of gas, and has become a source of considerable profit to the gas companies, being sold under the name of ammoniacal liquor.

Experiment 234.—*Ammonia from Animal Matter.*—Burn in a test-tube almost any animal substance, such as bone, flesh, hair, or horn, and in the top of the test-tube place a piece of turmeric paper. (See Experiment 228.) The paper will turn brown, owing to the escape of ammonia. It is sometimes termed spirits of hartshorn, from its being originally produced by burning that substance.

Experiment 235.—*Ammonia from Coal-Gas.*—Hold a piece of moistened turmeric paper over a jet through which coal-gas is passing; the paper will turn brown if ammonia is present.

Experiment 236.—*Another Test for Ammonia.*—Hold a feather dipped in muriatic acid over any liquid or gas containing ammonia : dense fumes of sal-ammoniac will be produced, owing to the combination of the two gases.

Experiment 237.—*Smelling-Salts.*—Ladies smelling-salts are simply carbonate of ammonia scented with an essential oil. To a little carbonate of ammonia add a small portion of lime; mix well together, and add a few drops of oil of bergamotte, and keep in a close-corked bottle.

Experiment 238.—Put a little carbonate of ammonia in a Florence flask, and heat by the spirit-lamp. The salt will sublime to the cool side of the flask, in the shape of minute crystals.

Experiment 239.—The smell from stables is owing to the presence of ammonia. To detect it, take into a stable a bottle containing muriatic acid; on uncorking it a dense smoke of sal-ammoniac will at once be produced. (See Experiment 203.)

Experiment 240.—*To restore faded Dresses or Ribbons.*—Put any of these articles, whose colour has faded, into a drawer with a smelling-bottle uncorked. The ammonia escaping will restore the blue colour of those which have been changed by acid vapours.

Experiment 241.—Hold a piece of red-coloured litmus paper over a bottle from which ammonia is escaping; the blue colour will be restored as in the last experiment.

Experiment 242.—Ammonia, as we observe by these experiments, is a gaseous body, and may be produced by heating together some sal-ammoniac and lime in a Florence flask. On fitting a bent tube thereto, and receiving the gas into water, the liquid will absorb the ammonia rapidly, and liquid ammonia, as it is termed, is produced. Ammonia is composed of two gases, hydrogen and nitrogen, and is thus, by the union of these two, always afforded when bodies containing these gases are either burned or putrefy.

Experiment 243.—*Absorption of Ammonia by Ice.*—Drop a piece of ice into a bottle containing ammoniacal gas : the ice will be speedily melted and the gas absorbed.

EARTHS.—CLAY, FLINT, LIMESTONE, ETC.

Another class of bodies which are oxides of metals are the earths, of which the crust of the world is formed. All these, with the exception of silica, contain metals. And lately Mons. Sainte-Claire Deville, of Paris, has, by the liberality of the Emperor Napoleon, been enabled to produce in quantity a most valuable metal called aluminium, which promises soon to replace silver and other metals for purposes of domestic and general use. Indeed, the very clay and bricks which are so common amongst us promise soon to be productive of specimens of the most *recherché* class of metallic manufactures.

We shall take the earths in the following order :—

Alumina.	Baryta.
Lime.	Strontia.
Silica, or flint.	Magnesia.

Experiment 244.—*Alumina.* — Common clay is composed chiefly of this earth. Alum, again, is largely produced from a clay slate. Alumina may be produced by adding to a solution of alum some carbonate of potass; when pure, it is a white powder, containing a good per-centage of water. The cause of the colour of clay is owing to the presence of oxide of iron.

The metal aluminium is with difficulty obtained from alumina. Mons. Deville's process is as follows :—Chloride of aluminium is formed by passing chlorine gas over a mixture of clay, charcoal, and sugar. The chloride is then decomposed, by melting it with sodium, which, with the chlorine, forms common salt, leaving the metal free; the aluminium is then melted with common salt, in a crucible, and cast into bars, or ingots.

Aluminium thus produced has much of the appearance of highly-polished zinc. It is very light, not weighing much more than twice its bulk of water; or, in other words, it weighs about the same as an equal bulk of glass. It is acted upon by few of the acids. But the alkalies in solution speedily convert it into alumina, which is its oxide.

Alumina is largely used in potteries, and forms the chief portion of china and crockery-ware. It is employed for making artificial gems, and is found in the emerald, ruby, and other precious stones.

Experiment 245.—Alumina is used in dyeing. For this purpose it is employed as a mordaunt; that is, to attract and retain the colouring-matter of the dye. Into a hot solution of cochineal, pour a solution of alum and a little ammonia: a beautiful red colour will immediataly fall down. In dyeing, the goods are soaked in an alum solution, before being placed in the bath containing the colouring-matter; the alumina in the alum thus fixes the colour on the cloth or yarn.

Lime.—This earth is one of great value in daily life. The mortar of our houses, the bones of our bodies, the shell of the fish, and some of our largest mountains and rocks, are mostly composed of it.

Lime forms twenty-eight out of every fifty parts of chalk or marble, and is obtained on the large scale by burning either of these minerals in lime-kilns.

EXPERIMENT 246.—*To obtain Lime.*—Heat some chalk in an iron ladle for some time. The carbonic acid of the chalk is driven off, and nearly pure lime remains.

EXPERIMENT 247.—*Heat from Lime.*—Pour a little water on some fresh-made lime: great heat is produced. During the summer of 1859 many sheds were set fire to, owing to a heavy thunderstorm causing lime, stored in wooden houses, to slake and give out heat. It is a common practice amongst the labourers near London to heat their breakfasts by placing a little lime outside of their tin cans, and then moistening it with water.

EXPERIMENT 248.—*Lime-Water.*—Lime is very slightly soluble in water. Shake a little fresh lime up with water in a bottle, and leave it to settle. The clear liquid is lime water, such as is used in carbonic acid experiments.

The bottle must be kept well corked, owing to the attraction lime has for carbonic acid.

EXPERIMENT 249.—*Mortar.*—Expose a little clear lime-water in a saucer to the air. The lime will form a pellicle or skin of chalk on the surface, by absorbing carbonic acid from the air. It is owing to this that lime eventually becomes solid, and is fit for use in making mortar.

EXPERIMENT 250.—Add a little muriatic acid to old mortar; effervescence will take place, owing to the escape of carbonic acid gas.

EXPERIMENT 251.—*Lime is Alkaline.*—Put a small piece of lime on turmeric paper, and moisten with water. The turmeric paper will turn brown. (See Experiment 228.)

EXPERIMENT 252.—*Egg Shells are composed of Lime.*—Heat some egg shells, as in Experiment 246, and lime will be left in the ladle.

EXPERIMENT 253.—*To put an Egg into a narrow-necked Bottle.*—Leave an egg in some strong vinegar, or in some weak muriatic acid, for some hours. The lime will be dissolved away, and the egg will be quite soft. It is to be gently pressed into the neck of the bottle, and when inside a little ammonia and water added. The egg will regain its old shape speedily, and be quite a puzzle to your young friends, as to how it was got inside.

Poultry require earth containing lime to peck at, otherwise the eggs laid would be without shells; even pea-plants will not afford peas unless lime is present in the soil in which they grow.

EXPERIMENT 254.—*Lime from Bones.*—Heat some bones strongly in an *uncovered* ladle. A white substance is left, which is chiefly lime.

EXPERIMENT 255.—*The Solidity of Bones is owing to the presence of Lime.*—Keep bones for some time in a strong solution of muriatic acid. The solid texture will be lost, and the bones will become quite soft.

The difference between the solid character of the bone of a grown-up person and that of an infant, is owing to the comparative absence of lime in the bones of the child; and its continuous addition to the bone during the growth of the adult from the substances on which he feeds.

EXPERIMENT 256.—*Lime a powerful Disinfectant.*—Sprinkle some powdered lime on any putrefying body. The smell will be speedily arrested. During the summer of 1858 and 1859 several thousands of tons of lime were cast into the Thames, with the hope of destroying the offensive smell which arose from the putrefying matter of the sewers.

EXPERIMENT 257.—*Plaster of Paris.*—This substance is a sulphate of lime, and is largely obtained in Derbyshire, and near Paris. Crystals of sulphate of lime may be found in the clay round London, especially in some parts of the banks of the New River.

The plaster casts sold by the Italian boys are made of it, by mixing its powder with water, and pouring the liquid into moulds. It soon becomes solid, and takes an exact impression of the mould.

To copy a Coin or other Object.—First slightly oil the surface with sweet oil, and form round the coin a paper rim, to prevent the escape of the liquid; then mix the plaster of Paris with water; stir it up quickly, and pour it on to the surface of your coin. After the plaster is solid, pare off the superfluous edges, and the copy will be complete.

Busts are taken from life by the same means, but we strongly advise our young friends not to attempt this, lest they should encase a friend in a solid stone covering, and require the use of a chisel to remove the plaster. An accident of this sort occurred to a young friend of our acquaintance who was desirous of taking the bust of a sister. The young lady nearly lost her life by the plaster getting into the mouth and nostrils. As the plaster soon "sets," or becomes solid, take care to leave none in any vessel, but immediately wash it out after use.

EXPERIMENT 258.—To give a polished appearance to plaster casts, rub them over with a solution of curd-soap in water.

EXPERIMENT 259.—Coloured casts may be obtained by mixing with the plaster Prussian blue, chrome yellow, &c., which will impart their individual tints to it.

Silica, or Flint.—This earth is very abundant in nature, forming a large proportion of the sand of our sea-shores, and also of the granite and other rocks of mountainous regions. Its uses are very various, even from the manufacture of glass of every kind, of which it forms the most essential part, to the employment of stone for our houses, and flag-stones on which we walk. It is found also in a variety of grasses, to which it sometimes acts as a backbone. Our young friends may distinguish it easily, by rubbing the grass between the fingers; it sometimes is so sharply crystallized as to cut the hands, when engaged in laying grass aside, or in plucking sedges. The black stones found in chalk are masses of flint supposed to have been formed by the silica having been deposited in animal and vegetable substances; and thus to have replaced their solid tissues. The beautiful mineral "quartz" is a crystallized state of this earth.

EXPERIMENT 260.—Silica may be obtained pure by fusing sand in a crucible with four times its weight of carbonate of soda. When cool, the mass is to be broken up, and muriatic acid is to be added to it; the silica falls down in a jelly-like shape. If this is dried and then washed, a white gritty powder is obtained, which is pure silica.

The most interesting manufacture in which this substance is employed is that of glass, and our young friends should embrace the first opportunity of seeing over a glass-work. To give some idea of the mode of making glass, we must ask you to imagine a circular furnace with a tall chimney, having, say six holes, each of which communicates with a large pot, holding several hundredweights of what is called "metal," in a melted state. This "metal" is made up of sand, red-lead, and an alkali; potass being used to make hard, and soda for soft, glass. By hard and soft glass we mean that such glass is with difficulty or easily melted.

After these ingredients are well mixed and fused at an intense heat, a workman takes a long tube, and dipping its end into the melted glass, withdraws a small portion. If he intends to form a bottle, he blows through the tube until the vessel has arrived at the proper size. On shaping the bottle completely, he breaks it from the tube by touching the neck part with a piece of cold iron. The vessel breaks off at once, and then requires annealing.

Unless glass were properly annealed, it would break on the slightest change of temperature. This is effected by heating the glass and then allowing it to cool very gradually; and on the perfection of this process depends the quality of the different glass vessels we use in domestic life.

Glass is cut by means of a lathe, on a wheel of which emery powder is strewed, and the best kind of glass is generally employed for this purpose; hence the preference still held by our older housewives for articles of *cut glass* manufacture.

Plate glass is made by rolling glass something after the same fashion as we roll paste. It requires polishing, which is a process lately brought to great perfection.

Common window-glass is made by a very singular method, but we cannot convey an adequate description of it by writing; to be understood it must certainly be witnessed in action.

Artificial gems are made from silica coloured with various oxides of metals; but as this process also requires extensive arrangements, we shall not attempt to describe it.

Silicon, the base of silica, is a dark-brown powder. It is presumed to be something analogous to charcoal.

Baryta.—This earth has obtained its name from a Greek work, signifying heavy, it being the heaviest of all the different forms of earthy matter. Its chief use is as a mixture for fireworks; and to some extent it is employed as a pigment.

Experiment 261.—*To make Nitrate of Baryta.*—Add some nitric acid to carbonate of baryta, with a little water: the nitrate of baryta is thus formed, and may be crystallized by evaporating the solution. This is the salt employed for giving a green colour to flame. (See Experiment 191.)

Experiment 262.—Chloride of barium is chiefly used as a test for sulphuric acid. It is easily produced by using muriatic acid, instead of nitric, and proceeding as in the last experiment.

Experiment 263.—Strontian is an earth almost exclusively employed by fire-work makers. Its nitrate can be obtained by adding nitric acid to the carbonate, and proceeding as with baryta. (See Experiment 261.) It is employed to give a red colour to flame. (See Experiment 190.)

Magnesia.—This earth is almost exclusively employed in medicine, and our young friends have, no doubt, often made acquaintance with it under the form of Epsom salts. It is found in sea water, mineral waters, in oyster shells, and in mountain limestone.

Experiment 264.—*Epsom Salts.*—To prepare these, pour a little dilute sulphuric acid on the white magnesia, sold at the chemists; leave the solution exposed to the air, and in a few days sulphate of magnesia will appear in crystals. The title Epsom salts was given to this salt owing to its being found in springs near Epsom. It is found, however, in the majority of mineral waters.

Besides the earths we have mentioned, there are others rarely met with, such as glucina, zirconia, yttria, thorina, and lithia, of which it will be sufficient for us just to mention their names. Our limits will not permit us to point out to you the various relations in which the earths stand to us in daily life. They form our bones and teeth; they are found in our food, such as bread, milk, and flesh of all sorts; and, in fact, they seem to serve an analogous purpose in the animal, vegetable, and mineral kingdom,—that of giving firmness and solidity to their structure.

MISCELLANEOUS EXPERIMENTS.

In the foregoing pages we have been endeavouring to give you some general idea of the nature of the most interesting elements and compounds embraced in the study of chemistry; omitting those which are either rare, or not of general interest to young readers. We shall now, without reference to arrangement of any sort, present you with various miscellaneous experiments; so that whilst they may afford you amusement, they may at the same time act as a sort of exercise in the different rules and laws we have previously laid down. We shall offer little or no explanation, but leave you to refer to what we *have said* for the purpose of understanding what we *are about to say.*

EXPERIMENT 265.—*To crystallize Sugar.—Sugar Candy.*—Make a strong syrup by dissolving brown sugar in boiling water. Hang in it a few small strings—on these large crystals will form, provided the syrup is allowed to cool gradually.

EXPERIMENT 266. — *To make Crystal Baskets.* — Dissolve some sulphate of copper in boiling water until no more is taken up. Then introduce a basket, made of copper wire, covered with cotton. As the liquid cools, the crystals of the salt will be deposited on the cotton covering the wire; and, when complete, will form a handsome chimney ornament. The covered wire may be obtained from any wire merchant; if you cannot easily get it, cap wire will answer for the purpose.

EXPERIMENT 267.—*To bleach Straw Bonnets.*—Wash the bonnet carefully from grease, &c., in the usual manner. It should then be attached to the top of a box, say eighteen inches high. In the lower part of the box, beneath the bonnet, place a ladle of burning sulphur. After a short time the straw will attain a light colour, and will be fully bleached. (See Experiment 101.)

EXPERIMENT 268.—*To silver Ribbons.*—Write on a white silk ribbon with a solution of nitrate of silver; then place the ribbon immediately in a jar of hydrogen. The silver will be reduced on the ribbon surface in the metallic state.

EXPERIMENT 269.—*To detect Copperas in Ale or Porter.*—Add a solution of prussiate of potass, and, if iron is present, prussian blue will be at once thrown down. (See Experiment 145.)

EXPERIMENT 270.—*To detect Alum in Bread.*—Boil the soft of the bread for some time in water. Filter the liquid, and when cold add to it chloride of barium or nitrate of barytes. If either alum or plaster of Paris are present, a white powder will be thrown down.

EXPERIMENT 271.—*To detect Sulphuric Acid in Vinegar.*—Add the solution of chloride of barium to the vinegar, and, if any sulphuric acid is present, sulphate of baryta will be formed, as in the last experiment.

EXPERIMENT 272.—*Stream of Blue Fire.*—Melt sulphur in a ladle until it burns briskly; let it then drop through the air from a height of ten or twenty feet; it will form one continuous stream of blue fire.

EXPERIMENT 273.—*Lead in Water.*—Lead cisterns and pipes often render water poisonous. Through the suspected water pass a little sulphuretted hydrogen gas. If the metal be present, it will be thrown down as a dark-brown powder. (See Experiment 109.)

EXPERIMENT 274.—*Lime in Water.*—River and spring water are often hard through containing lime. To such add a solution of oxalic acid and a little ammonia, and oxalate of lime will be precipitated if lime is present.

EXPERIMENT 275.—*To take Marking Ink Stains out of Linen.*—Soak the part in a strong solution of corrosive sublimate, and afterwards wash well in water.

EXPERIMENT 276.—*To render Hard Water Soft.*—Dissolve some lime in a pail of water, and add the clear solution to the hard water. The lime takes up the excess of lime dissolved in the hard water, and forms chalk. This renders the hard water soft, by depriving it of the soluble bicarbonate of lime.

EXPERIMENT 277.—*To make Aërated Lime Water.*—Pour a tablespoonful of lime water into a tumbler; to this add a bottle of soda water. This forms a solution of bicarbonate of lime, and is an excellent remedy for acidity of the stomach.

EXPERIMENT 278.—*To detect Starch in Sweetmeats, &c.*—Dissolve them in cold water; add a little solution of iodide of potassium. On stirring the mixture with a glass rod, on which are two or three drops of sulphuric acid, if starch is present, the whole will turn of a dark-blue colour.

EXPERIMENT 279.—*To melt a Threepenny-piece in a Walnut Shell.*—Into the shell, with the coin, put a mixture of one part of chlorate of potass, with twice its weight of pounded lump sugar. On setting fire to this, sufficient heat will be afforded to melt the silver.

EXPERIMENT 280.—*Light and Heat from Sugar by means of a Cold Liquid.*—Into the mixture of chlorate of potass and sugar drop a little sulphuric acid, by means of a glass rod. The mixture will at once inflame.

EXPERIMENT 281.—*To make a Solid from Two Liquids.*—Prepare a strong solution of chloride of calcium, by dissolving chalk in muriatic acid. Into this pour a solution of sulphate of soda. On stirring them together, they will soon afford a solid, which is plaster of Paris. (See Experiment 257.)

EXPERIMENT 282.—*Liquid giving a Green Flame.*—Dissolve boracic acid in spirits of wine. On being set fire to, a rich green flame is produced.

EXPERIMENT 283.—*To crystallize the Surface of Glass.*—Wash, by means of a painter's brush, the surface of the glass with a hot solution of either Epsom salts, alum, or sal ammoniac. As the glass cools, beautiful crystals will be deposited on its surface.

EXPERIMENT 284.—*Frosted Trees.*—Fix in the top of a glass jar a twig of any plant, such as of thyme, marjoram, or rosemary, and place it over a piece of hot iron, on which throw some benzoic acid. The acid will sublime to the twig and top of the jar, and beautifully "frost" over the surface of the leaves, &c.

EXPERIMENT 285.—*To make Tea-spoons which will melt in a Cup of Tea.*—Melt together the following metals in the proportions named, and have the alloy made into tea-spoons:—

Bismuth	eight ounces.
Lead	five ,,
Tin	three ,,

These spoons, although presenting the appearance of Britannia metal, will immediately melt on being stirred in a cup of hot tea, to the great amusement of young folks.

EXPERIMENT 286.—*Bone-forming and China-mending.*—The bones of the body are continuously supplied with lime by the food, and china may by an analagous process be mended when broken. For this purpose bind carefully together the different pieces of the broken article, and boil them for six hours in new milk. The whole will be again solidly united; and owing to the deposition of the lime from the milk in the cracks, the article will become as solid as when first made. Tape answers best for binding the pieces into the original shape.

Experiment 287.—*Coloured Fire-papers.*—Dip blotting-paper into a mixture of nitric and sulphuric acids. After leaving it for two or three minutes, wash it till every trace of acid is lost. When dry, dip the paper into a strong solution of chlorate of potass, and afterwards into a solution of nitrate of strontian for a red flame; nitrate of baryta, or a solution of boracic acid, for a green. The paper should then be carefully dried. When ignited these papers afford brilliant flames of the colours we have named, and burn rapidly, like gun-cotton.

Experiment 288.—*Salt from the Hands.*—Rinse the hands in distilled water, and to this add a solution of nitrate of silver. The common salt obtained from the perspiration will thus be easily detected, by the formation of chloride of silver.

Experiment 289.—*To detect Starch in Sugar.*—Brown sugar is often adulterated with potato starch. This may be detected with a solution of iodide of potassium and a drop of sulphuric acid, by the blue colour produced when starch is present.

Experiment 290.—Common tallow candles during combustion gradually give less light, owing to the wick not being consumed away. Incline one of them a little to one side. The oxygen of the air will then have access to the red-hot wick, and the latter will gradually burn away. We have suggested this plan to many working persons as an easy way of making tallow candles snuff themselves, and by a little care the process will go on, and save all further trouble, until the candle is completely consumed, and the tallow will not run down the sides.

Experiment 291.—Dissolve some tallow in a strong solution of soda, and it will form soap (see Experiment 232); add some water to it, and afterwards some sulphuric acid. The solid part of the soap will now separate. It is called stearine, and it is of this that "composite" candles are made.

Experiment 292.—Place a drop of olive oil and one of otto of roses on two separate pieces of paper. Hold each over the spirit-lamp. You will find that the olive oil will remain, whilst the otto of roses entirely evaporates. Hence the former is termed a *fixed* oil, and the latter a *volatile* oil.

Experiment 293.—Place any one of the following articles of food in the bowl of a clean tobacco pipe, and heat it red-hot for some time in a fire, as bread, flour, potatoes, peas, beans, and meat. From any one of these you will obtain some white ashes. These are formed of the earths gathered from the soil in which the vegetable grew, or, in the case of meat, from the grass on which the animal fed. When taken into our bodies, they go to form bone (see Experiment 255).

EXPERIMENT 294.—Try the same method with sugar. You will find no earthy matter produced from it. Hence sugar is not sufficient by itself as an article of food to sustain the growth and substance of the body.

EXPERIMENT 295.—Put a small piece of clay out of the garden or field, into a Florence flask, and add to it a little muriatic acid and water. Boil the contents of the flask over the spirit-lamp. When cool filter the liquid left through some blotting-paper. Try this for the presence of iron by adding to it some of the solution of prussiate of potass. A blue colour (prussian blue) will be at once produced (see Experiment 145), owing to iron being present in the clay.

EXPERIMENT 296.—Put a little Epsom salts and common salt into a glass of water. When dissolved, add some solution of chloride of barium. This will separate the sulphuric acid of the Epsom salts in the form of a white powder. Filter the liquid through some blotting-paper, and when quite clear add to it some solution of nitrate of silver. This will separate the chlorine from the common salt also in the shape of a white powder.

EXPERIMENT 297.—Having obtained the two white powders, separately, expose them to the action of the sun's rays. That obtained from the Epsom salts will retain its white colour; but that produced from common salt will turn black by the action of light. Hence, by these simple means, these two powders may be distinguished.

EXPERIMENT 298.—The last three experiments illustrate a branch of chemistry called *analysis*. By extending the same principles, the chemist is enabled to detect the presence of poisons, &c., in cases where his skill is required. He often obtains the result of his processes in what is called a precipitate. Thus, dissolve some camphor in spirits of wine; the solution will have the appearance of water. But now add some water to it; the camphor will immediately separate from the spirit, and fall down as a white powder. This is called a *precipitate*.

EXPERIMENT 299.—Take some of the bright yellow scales often seen in pieces of coal, and having powdered them, heat them red-hot in a crucible, or in the bowl of a tobacco pipe. The sulphur they contain will thus be driven off. Now add to them either sulphuric, nitric, or muriatic acids, together with a little water. They will soon disappear. On testing the solution with prussiate of potass, the prussian blue will be produced, proving that iron was present. These yellow scales are composed of iron, combined with sulphur.

EXPERIMENT 300.—Dissolve some prussian blue obtained in the last experiment, or otherwise, in a solution of oxalic acid. It will afford a fine blue liquid. By adding a little gum, it may be employed as a blue writing-ink.

EXPERIMENT 301.—Boil a piece of calico in a strong infusion of logwood, made by boiling logwood chips in water, and straining off the clear liquid. Afterwards soak the calico for some time in a solution of copperas (sulphate of iron). The cloth will thus acquire a dark slate colour. By repeating this process twice or thrice, you may dye it of a black colour.

EXPERIMENT 302.—On a piece of calico dyed as above, press a piece of wood, which has been wetted with a strong solution of citric acid. The colour will be discharged, and a white mark will be produced. By similar means calico printers produce the white patterns on ladies' muslin dresses.

EXPERIMENT 303.—Soak a piece of white cotton cloth in a solution of sugar of lead (acetate of lead), then introduce it into a solution of bichromate of potass. The cloth will be dyed of a rich yellow colour. By this process gloves and other articles may be dyed of a colour extending from a primrose to a light orange tint.

EXPERIMENT 304.—Soak some cotton cloth or yarn in a solution of copperas, and afterwards dip it into a weak solution of bleaching powder. It will become of a brown colour.

EXPERIMENT 305.—Wash some safflower, which you can obtain at the druggists, with water till all the yellow colour is removed and the water passes off colourless. The remains of the safflower must now be soaked for a few hours in a solution of carbonate of soda in *cold* water. Into this liquid dip a piece of white calico, and you will observe only a dirty red colour produced. Transfer it to a solution of citric acid, and you will immediately find that a most beautiful rose tint is afforded, owing to the acid " bringing out " the red colour of the safflower. By similar means the fine rose colour dyes of silk dresses and ribbons are produced.

EXPERIMENT 306.—Put some of the red leaves of the cactus flower into a solution of carbonate of soda, and proceed throughout the process as described in the last experiment. A rich red colour will be afforded by the leaves.

EXPERIMENT 307.—Into a kettle, which from long use has been coated with "fur," pour a very weak mixture of muriatic acid and water. The "fur" contains lime, and the acid dissolving this will soon clean the metal surface. In large steam-boilers this fur accumulates very rapidly, and has sometimes been the cause of serious accidents. We have seen two large cart-loads of this "fur" removed from a forty-horse steam-boiler, at the end of each month's work. After cleansing the kettle as above, wash it carefully with cold water.

EXPERIMENT 308.—Spirit bottles are often coated with a fur through the alkali used in rectifying adhering to their inside surface. To such apply a little vinegar or dilute muriatic acid, and the coating will at once disappear.

EXPERIMENT 309.—The inside of water bottles often become coated with a vegetable growth. This is easily removed by a solution of soda. The bottoms of ships are often covered so thickly in a similar manner, as to impede their progress through the water.

The above experiments afford instances of the application of Chemistry to manufacturing purposes, and will give the hint to our young friends, which, if they carry out, may suggest to them some cases where Chemistry may be made useful in home matters.

EXPERIMENT 310.—*The Fire Cloud.*—This experiment is very beautiful, but is scarcely fit to be tried in a room, as it tends to blacken the ceiling, and is somewhat dangerous to an inexperienced person. We will, however, give full directions, so that older hands may, if they please, help to amuse "youths" of all ages.

Have made a strong copper vessel, which should be about ten inches long and three inches in diameter, and of the shape of an ordinary bottle. Into this, two pipes must be soldered, each reaching nearly to the bottom of the vessel; into one of these a jet and stopcock should be screwed, and to the other a stopcock must be also fixed, to which a syringe can be screwed. A strong solution is to be made by putting about four ounces each of nitrate of strontian and chloride of barium into a pint of the best spirits of wine, and shaking them up repeatedly until as much as possible is dissolved. To use the apparatus, pour into the bottle as much of the clear solution as will half-fill it through either of the tubes. Open at the same time the other stopcock, to allow of the escape of air. As soon as the bottle is half-filled, close the stopcock of the jet, and pump in, by means of the syringe, a large quantity of air through the other tube. With respect to this, we would advise fifty strokes of the piston of a syringe eight inches long and one inch in diameter.

Then close the stopcock, remove the syringe, and put the copper bottle into some hot water, to heat the spirits. The bottle should be wrapped in a cloth, to protect the hands from heat. Standing on a chair or pair of steps, direct the jet to the ceiling; open its stopcock, the spirit will fly out, when the vapour must be ignited by an assistant. The effect is very fine, if all is properly managed, as the most beautiful and different coloured clouds of fire will extend over the whole surface of the ceiling. The subjoined diagram will explain the whole sufficiently; it represents a section of both bottle and syringe.

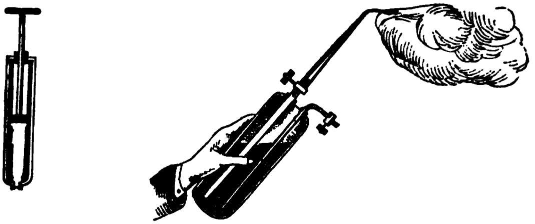
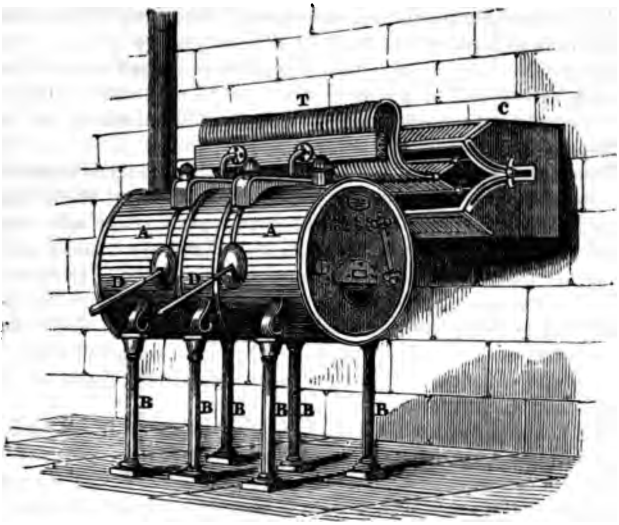


Fig. 56.

We just add to this description a few words of caution. Take care that the bottle is made of *stout* copper, that every part is air-tight, and lastly, as the spirit is very inflammable, never conduct any part of the preparatory process in a room where there is either lamp, candle, gas-light, or fire.



THE HYDRO-ELECTRIC MACHINE.

EXPERIMENTS IN ELECTRICITY.

In our Chemical experiments we have often had to call in to our aid both light and heat; indeed, without the assistance of one or other of these forces (as they are called), we could have had but little or no success.

We need scarcely remind even the youngest of our friends, that matter of any sort can not put itself into motion. Now, there are but few powers in nature, that we are acquainted with, that are employed for this purpose, and they have been called respectively light, heat or caloric, electricity, and magnetism. The three first are found in every body we have yet examined, and the recent researches of Dr. Faraday and others lead us to believe that almost everything is susceptible of even the influence of magnetism.

We now propose offering a series of experiments illustrating the nature and application of these various powers; and we can promise a rich fund both of amusement and instruction, during our progress,—electrical machines, galvanic batteries, electrotyping, shocking-machines, magnets, telescopes, microscopes, magic lanterns, photography, and a vast variety of other such matters will be pressed into our service. And as we have already attempted, so we shall continue to make the pursuit of our experiments both easy, safe, and economical to all our readers.

Electricity is, comparatively speaking, a modern branch of science, although some of the results of electrical disturbance have been known for ages. Some thousand years ago it was known that if amber was rubbed briskly it attracted small pieces of feather and other light substances to its surface. In fact, the name of the science is derived from the Greek word *electron*, signifying amber; and, doubtless, the ancients must have been acquainted with many of the facts of the science, yet they had not, or did not exercise the power of gathering together and generalizing these facts.

We have already said that electricity is found in all bodies; we shall now name some experiments by which you may call this force out from its latent state. By the term *latent*, we mean that whilst the force exists in all bodies, yet it is not observed by our senses, until we use proper means to bring it out. It then becomes what we term *sensible*.

EXPERIMENT 1.—Rub a piece of sealing-wax on the coat-sleeve, and then hold the rubbed end near some pieces of paper. The papers will leap from the table and for a short time adhere to the wax; they will then fall off, again to return, the reason of which we will explain presently.

EXPERIMENT 2.—Warm a piece of glass tube, and rub it with a dry silk handkerchief. Hold it over the feathers or paper as before, and you will have the same result.

EXPERIMENT 3.—The same may be done with amber, resin, gutta percha, &c., each of which you can try.

EXPERIMENT 4.—*Electricity from Paper.*—Dry a piece of foolscap or writing paper well before the fire, lay it down flat on the table, and rub it briskly by means of india-rubber; quickly lift it off the table, and you will find it inclines to adhere to its surface; present your knuckle to the paper as it hangs in the air, and you will observe it approach to your hand. This is an instance of what we call *electrical attraction.*

EXPERIMENT 5.—*To obtain a Spark from Paper.*—Try the same experiment in a dark room, and you will find a small spark pass between the paper and your knuckles. This is termed the electric spark.

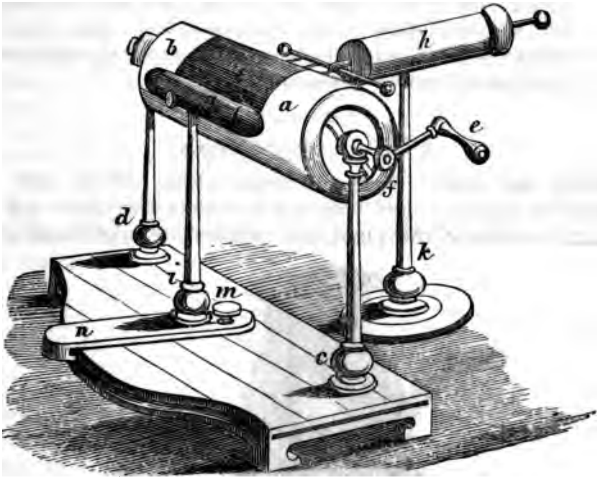
EXPERIMENT 6.—*Electricity from the Back of a Cat.*—Rub the *fur of a black* cat from the head to the tail by means of a dry handkerchief or by the hand; the fur will rise up in all directions, each piece seeming to drive the other away. This has been termed *electrical repulsion.*

Experiment 7.—Try the same experiment in a dark room, and by presenting your knuckle to the edge of the fur you will find a kind of pricking sensation, and at the same time observe minute sparks passing.

These experiments are very simple modes of obtaining electricity by friction, and we here remark that the spark produced by rubbing the paper or the cat's back is exactly the same in its nature and cause as a flash of lightning, each being produced by a disturbance of the electric force.

Having thus shown how easily electricity is obtained by the

Fig. 1.



THE CYLINDRICAL MACHINE.

Fig. 1.—In the above diagram we have an illustration of the usual form of the Cylindrical Machine, in which—

a b represents the glass cylinder.
c d the legs by which it is supported.
e f the winch handle by which the cylinder is turned.
g the rubber.
h the conductor.
i the glass support to the rubber.
k the glass support to the conductor.
m n a moveable foot, by which the distance between the rubber and the cylinder can be adjusted.

These arrangements vary slightly, according to the views of the maker, but the different parts are common to every form of machine.

friction of various substances, we shall proceed to explain how we are enabled to obtain sufficient of the force for us to examine its effects on a large scale; and for this purpose we shall require the assistance of one or other of the different sorts of electrical machines which have been invented by various students of the science.

Electrical machines are chiefly of two classes; namely, the cylindrical and the plate machine. Of course, their cost varies in proportion to the size; but one suitable for our young friends may be purchased at a philosophical instrument maker's for a small sum.

The Cylindrical Machine, one of which is represented on the preceding page, is perhaps the cheapest of the glass kind of these arrangements. The description we have appended will give you an idea of its construction, and the mode of using it we shall explain further on, giving you at the same time full instructions as to special matters, an attention to which will ensure success in your experiments.

THE PLATE MACHINE.

These are made in various forms, some having one, and others two rubbers; our illustration is of the latter class. At the top and bottom of the plate, the rubbers are fixed and their pressure on the glass is regulated by means of thumb-screws. From each, side-arms proceed, which terminate in the chief con-

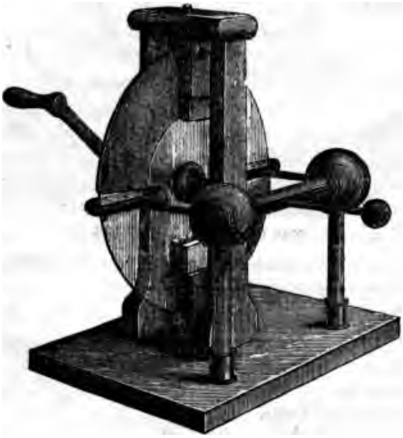


Fig. 2.

ductor. Both in this, and in the cylindrical machine, that portion of the conductor facing the glass is covered with points, which, as we shall explain hereafter, have the effect of collecting the electricity from any surface where it is set free. Fig. 2 illustrates one of the most usual forms of the plate machine.

We are indebted to a gentleman named Simmonds, residing in the West of England, for a new and cheap gutta-percha electrical machine. He deposited one in the London Polytechnic some years ago, and as we have tried it in all sorts of weather, we have no hesitation in recommending it as a cheap and effective substitute for the usual apparatus. The one we refer to had a plate of gutta-percha twelve inches in diameter, with rubbers of hare-skin. And we have given a shock from it by a Leyden jar to thirty persons at one time. It requires no amalgam, and if kept clear of dust, is always ready at a moment's notice.

The tray, supports, and plate are all made of gutta-percha; in fact, every part of the machine, excepting the rubber, is of that material. The rubbers are made either of doe, rabbit, or hare-skin, with the fur next the gutta-percha plate. An inspection of one of the ordinary glass machines, or a careful study of ours, in fig. 2, will give the best idea of the arrangements of each separate part, the student bearing in mind that, as regards everything but material, he must follow the construction of the common plate machine.

THE ELECTROPHORUS.

This is a simple arrangement, by which a considerable amount of electricity may be obtained; and, to our young friends, it presents a ready mode of giving shocks and sparks with a Leyden jar, which we shall describe further on.

To make an Electrophorus.—Have made at the tin-smith's a circular tray of zinc, twelve inches in diameter and half an inch deep. Fill this with melted yellow resin up to the edge of the tray (A, fig. 3). Now fix to a circular plate of zinc, which should be quite flat and its edges smooth, a piece of gutta-percha tube, to form a handle (B). The zinc plate (C) should be nine inches in diameter.

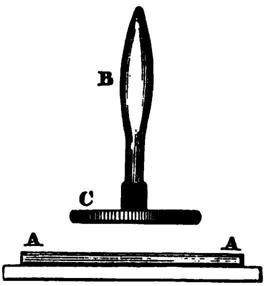


Fig. 3.

When the resin in the tray (A) is quite cold, rub its surface briskly with a warm dry piece of flannel; then place the metal plate (C) on the resin, holding it by the handle. Now touch the top of the plate with the finger, and raise the plate by the handle two or three inches from the resin. On presenting your knuckle to the edge, you will find a spark pass. This may be often repeated by replacing the plate on the resin, touching it whilst there, lifting it up, and again obtaining the spark; or if you are charging a jar by this arrangement, you simply present the metal plate to the knob of the jar, and the spark, thus repeatedly passing, will charge it. You need not rub with the flannel each time, as one excitation answers for some time.

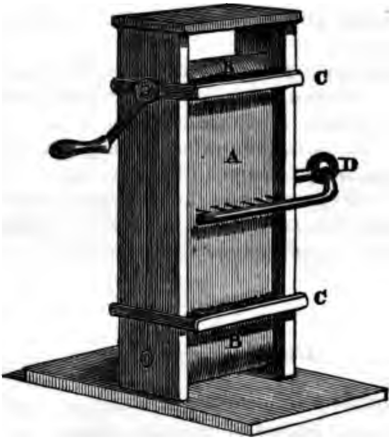


Fig. 4.

Fig. 4 represents another simple form of electrical machine, which, however, we have never tried.

An endless sheet of gutta-percha (A) is passed over two rollers (B B), and turned rapidly by a handle thereon. C C represents two rubbers, formed of hard hair brushes. The conductor (D) is furnished with points, and collects the electricity produced by the friction of the gutta-percha against the rubber.

A machine of the above construction is very easily made. The framework, and indeed every part, may be constructed of gutta-percha. As that material is a very poor conductor of *electricity,* and does not easily gather moisture on its surface, it presents many advantages when used in the construction of electrical machines.

Whenever the cylindrical or plate-glass machine is used—and we prefer a plate machine for most purposes,—the following precautions must be adhered to most carefully, to ensure you success in your electrical experiments.

1st.—Provide first two or three old silk handkerchiefs, and having dried them well before the fire, clean every part of the machine, legs, stand, plate, or cylinder, rubber, and conductor, completely from dust and dirt.

2nd.—If any marks are found on the glass, wash these off by means of spirits of wine and a soft rag.

3rd.—After every part of the machine is thus cleaned, throw over it a dry silk handkerchief, and place the whole near a fire, but not too close, lest you should crack the glass, until the plate or cylinder is a little warmer than the air of the room in which you are about to try your experiments.

4th.—The rubber must now be amalgamated. This is done by pulling back the silk flap, and gently laying on the cushion of the rubber an amalgam made of the following ingredients. They should be mixed in a clean mortar, only in quantities required for present use, as they are apt to spoil if kept long, and in such case the amalgam is worse than useless.

Recipe for electrical amalgam :

Zinc	one ounce.
Mercury.........	two ounces.

To make the amalgam adhere to the surface of the cushion, just smear it slightly with a little clean tallow, on which the amalgam may be spread with a knife.

5th.—The cushion being amalgamated, screw it towards the glass-plate, so as to press on it gently; turn the handle of the machine, and wipe the glass until all trace of grease, &c., is removed after it leaves the cushion. Replace the silk flap, and you should now find the machine in good working order, and giving off long sparks from the conductor to the knuckle.

6th.—Damp weather is the worst enemy to the electrician, and in such a case, the application of dry, warm cloths to every part of the machine is your only remedy. These must be continually used after each experiment, as we named in rule 1, to remove all moisture and dust, which may gradually accumulate.

7th.—In putting away your machine after use, keep it in a dry place, and on each time of using repeat all these precautions, and you will generally ensure success. The rubber should be re-amalgamated, being first cleansed of all that remains from a previous use. Dry and clean arrangements are the sheet anchor of the electrician.

The gutta-percha machines require no amalgam. They should be kept perfectly free from dust, and the same remarks apply to the electrophorus. Presuming that the machine is in good working order, we now proceed with some experiments on the electric spark.

Experiment 8.—Connect the rubber of the machine by means of a wire, with a gas-pipe or any metal such as a water-pipe, &c., for the purpose of ensuring a continuous action of the machine. Now turn the handle, and present the knuckle to within an inch of the conductor—a bright spark will pass.

Experiment 9.—Repeat this experiment, but first remove the wire attached to the rubber. The sparks will gradually decrease in strength until they nearly cease. This shows the necessity of the wire for the purpose of keeping up the production of electricity. Some recommend brass chain; but after long experience, we decidedly prefer wire, as supplying the most certain conductor.

Experiment 10.—Instead of the knuckle, present a dry glass rod: you will find that sparks will not pass. The same will happen if a rod of sealing-wax, gutta-percha, resin, or sulphur is used. These substances are therefore called non-conductors of electricity, because they do not allow it to pass over their surface. Metals and many other substances and liquids, are called conductors because the electric force is easily conveyed by them. All bodies are thus divided, electrically speaking, into these two classes.

Experiment 11.—Paste in a straight line on a piece of window-glass some small pieces of tinfoil, of about the size of a pea each, leaving between each of them a space of about the 1-16th of an inch, or less; attach to each end of the glass a strip of foil, and connect one of these ends to the earth or a gas-pipe, by means of a wire. Present the other end to within half an inch of the conductor of the machine. Sparks will now pass between each piece of foil, over the glass surface, but none will be seen on the foil, because the tin is a good conductor. A small metal knob should be fixed on the glass-plate at the end next to the conductor. (See figs. 5 and 6.)

Experiment 12.—Instead of window-glass, use coloured glass, on which paste the tinfoil. The spark will appear of the colour of the glass used, if viewed through it.

Experiment 13.—Thread on a piece of silk some beads of *glass, and steel* or brass, in the order of glass and metal alternately. To one end tie a brass ball, and to the other a wire reaching to the ground. Present, by means of a glass rod, the

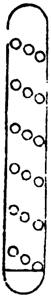


Fig. 5.

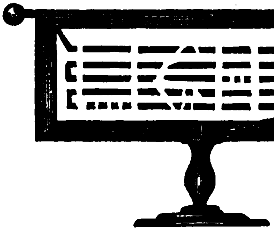


Fig. 6.

knob to a little distance from the conductor; a spark will pass through the whole length of the thread, broken at each glass bead.

Experiment 14.—Brass balls are much used by the electrician; their effect is to condense the spark. Instead of brass, small balls may be made of cork, covered with tinfoil. These answer very well, and a few should be kept ready. They are easily fixed on any object such as glass, &c., by means of a slit in the side.

Experiment 15.—Hold a brass ball near the conductor, and a spark will pass, as in Experiment 8. Instead of a ball, present a pointed wire. No spark will now be observed, but instead of this, you will see a peculiar appearance, called the electrical brush, as represented in fig. 7.

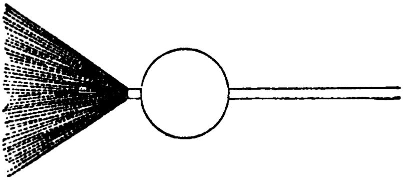


Fig. 7.

The effect of points is to disperse electricity, and for that reason, all surfaces of electrical apparatus are carefully rounded and polished. Lightning conductors are always made with *sharp points*, their object being the reverse of that we have just spoken of.

Experiment 16.—Place on the conductor a piece of grass turf. On presenting the knuckle, you will obtain no spark from the machine, owing to the diffusive power of the points of the grass. Any other pointed body will produce the same effect, if fixed to the conductor.

The edges of leaves and the tops of trees thus afford diffusive points to electricity during a thunderstorm. Owing to this, and to the conducting power of the solid trunks of trees, their vicinity is a most dangerous place. Many persons have lost their lives during storms, by taking shelter under tall trees. It is far safer either to walk on in the middle of the road, or to sit, or still better, to lay down until the storm is past. The same objection exists against the use of an umbrella in such circumstances.

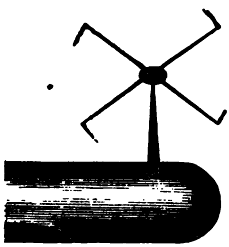


Fig. 8.

Experiment 17.—*The Electrical Windmill.*—Twist two wires with pointed ends together, so as to form an arrangement of this shape (fig. 8), and pass the point of a pin through a hole at the centre, so that the wires can easily turn round on the pin. The point of the pin should now be fixed, by means of a little bees'-wax, to the conductor of the machine. On turning the handle, the wires will commence to revolve, and present a little brush of flame at their points.

Experiment 18.—*Aurora Borealis.*—For this experiment an air-pump is required, and in the top of the receiver a brass plate is placed, through which a rod moves to and fro in an air-tight collar. The conductor of the machine is now attached by a wire to the ring at the top of the brass rod, and the plate of the air-pump to a gas or water-pipe. (See Experiment 9.) The rod should be drawn to the top of the inside of the receiver, and the air-pump worked until a good vacuum is produced inside. On now working the electrical machine, a beautiful long flame of a purple tint will pass through the whole length of the receiver, exactly resembling the aurora borealis. In fact, it is thought by philosophers that that splendid phenomenon of nature is produced by electrical discharges through the air at great altitudes, where the atmosphere has not so great a density as even that of the very slight quantity still remaining in the air-pump receiver. Fig. 9 will give you an idea of the entire arrangement.

Experiment 19.—The experiment may be tried in another way, by sealing a platina wire two inches long in the end of a *glass tube*, thirty-six inches long. The tube is now to be filled with mercury, and by keeping the finger on the open end, immerse it in a cup containing more mercury; remove the finger, and about six inches of the metal will run out, leaving a vacuum at the upper part of the tube. Support the tube by any convenient means, in an upright position, and connect the platina wire with the conductor, as in the last experiment. On working the machine, a bluish-coloured flame will pass between the platina wire and the mercury. The latter should be connected with the gas-pipe, as before directed.

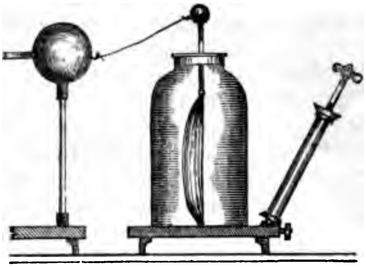


Fig. 9.

Experiment 20.—Place a wire pointed at the end on the conductor, and whilst the machine is in action, present to it the flame of a candle. The flame will be blown away; and if the hand or face is held near the point, a distinct draught of air will be perceived.

Experiment 21.—Make an electrical stool, by cementing four stout bottles into a piece of wood that has been baked in an oven; the wood may be an inch thick and twelve inches square. The object of the glass bottles is that they may serve as legs. These stools are generally made by cementing glass rods in the place of bottles, but either will do. The cement is composed of two parts of bottle-wax with one of bees'-wax, melted together. On the top of the stool place a sheet of gutta-percha, to make the insulation more complete. Now let a friend stand on the stool, and connect him to the machine by means of a wire; if you present your knuckle to any part of his body, you may obtain a spark from him if the machine is in good action.

Experiment 22.—Hold a teaspoonful of ether within half an inch of a brass ball which the person on the stool must hold in his hand. The ether will be at once ignited.

Experiment 23.—Let your friend comb his hair whilst standing on the stool in connexion with the machine. Every hair will be separated by what is called electrical repulsion.

Experiment 24.—Place a doll's head of hair on the conductor of the machine. The hair will all stand on end while the machine is being worked, in the way represented in fig. 10.

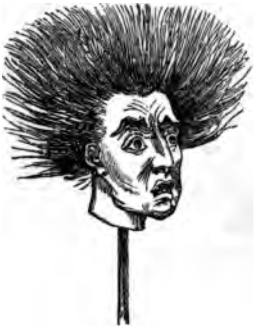


Fig. 10.

Experiment 25.—Cut a number of strips of tissue paper, about a quarter of an inch wide and six inches long. Fix them on a wire, and place the whole on the conductor of the machine. The paper will all separate as the hair did in the last experiment.

Experiment 26. — Present the knuckle or a brass knob held in the hand to either the hair (Experiment 24) or the paper in the last experiment, and either will at once collapse, owing to the escape of the electricity to the earth.

Experiment 27.—Obtain two pieces of pith, cut out from the inside of a branch of the elder-tree, and hang each of these to a thread from the conductor. They will immediately diverge, as in fig. 11, at P and N.

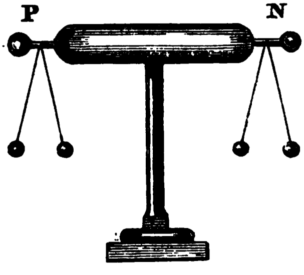


Fig. 11.

Experiment 28.—Electrometers or electricity measurers, and electroscopes or instruments for showing the presence of free electricity, are made by enclosing two strips of gold-leaf inside of a glass bottle. A wide-mouth bottle holding half a pint will do (see fig. 12, B) : on opposite sides of the inside two pieces of tinfoil, a quarter of an inch wide, are pasted, as D D. Have a small tin lid made to fit the top of the bottle, as at A; and to this fix, by a little gum water, two pieces of gold-leaf, half an inch wide and two inches long, as C C. The leaves of gold are to hang perpendicularly inside of the bottle, and may be fixed by means of a strip of tinfoil to the inside of the lid. When not in use, the gold slips will hang down in a straight line.

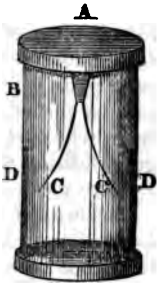


Fig. 12.

EXPERIMENT 29.—Bring near to the lid a glass tube which has been rubbed with a silk handkerchief; the leaves will immediately separate, as seen in fig. 12. In use, it is necessary that the bottle should be dry and slightly warm. This arrangement has been called the gold-leaf electroscope.

EXPERIMENT 30.—Whilst the gold-leaves are thus separated, bring near to the tin cover a roll of sealing-wax, excited by rubbing it against the coat-sleeve or by a flannel. The gold-leaves, instead of keeping apart, will instantly fall together again, owing to the wax presenting a different class of electricity to that of the glass.

Our young friends must bear this fact in mind, because in all our electrical experiments the different parts of our apparatus assume one or other of these two electrical states, and it is by disturbing electricity by friction or otherwise that we produce those opposite conditions which are called negative and positive.

The electricity in the above experiment obtained by rubbing the wax is negative; that obtained by rubbing glass is positive; and the reason of the leaves coming together again in our last experiment was simply that the negative electricity of the wax neutralized the positive of the glass, and thus a state was produced in which electricity of neither kind was evident. This result is termed by electricians "the restoration of the electric equilibrium."

We shall not trouble you with the question as to whether there are two sorts of electricity, or only one in a plus or minus state, as was advocated by Franklin. If you will only bear in mind what we have said, you will be in no great difficulty in the use of these terms when reading works on electrical science.

Again, two bodies similarly electrified repel each other. Thus the hair, the paper shavings, &c., in our Experiments 23, 24, and 25, were similarly electrified, and therefore showed the effect called *electrical repulsion*. In some of our following experiments the reverse will take place; and we shall, by arranging bodies in different electrical states, produce what is called *electrical attraction*, besides the effect of repulsion.

EXPERIMENT 31.—Hang from the conductor of the machine a small piece of tin-plate, and under this at two inches' distance place another tin-plate, connected with the ground; on the lower plate a few small pieces of elder pith (see Experiment 27) may be placed. On turning the handle of the machine, the pieces will dart up from the negative to the positive plate, and again falling when electrified, will be attracted towards the negative plate again.

EXPERIMENT 32.—*Dancing Dolls.*—Cut some figures, in the shape of men, &c., and use these instead of the pith balls. They will dance up and down so long as the handle of the machine is turned. Fig. 13 represents the apparatus generally used for the purpose. Take care that the edges of your tin-plates are smooth, for the reasons we named in Experiment 15.

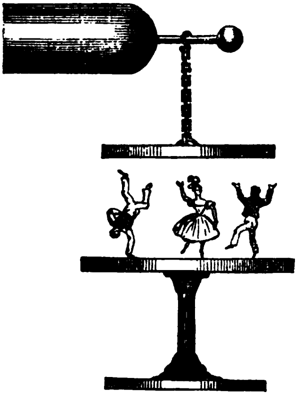


Fig. 13.

EXPERIMENT 33.—*The Electrical Pendulum.*—Hang, by means of a silk thread, a small pith ball between the conductor and a knob opposite to it, and connected with the ground. On turning the handle, the pith ball will commence to oscillate between the conductor and the knob. They may be two or more inches apart.

EXPERIMENT 34.—*Electrical Bells.*—The scientific instrument makers have an arrangement by which electricity may be made to ring bells. These are hung from a rod, and between them are clappers, which, when connected to the machine, strike the bells, and so produce a continual ringing by alternate attraction and repulsion. Fig. 14 illustrates the most usual form of this arrangement.

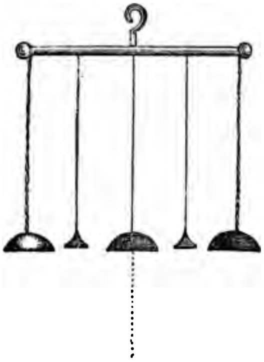


Fig. 14.

Experiment 35.—A vast variety of experiments may thus be made by these means,—see-saws, swing-boats, &c. We name these only, and leave our young friends to their own ingenuity in extending the examples we have afforded. They will be easily able to do this by bearing the principles in mind to which our experiments have had reference.

The Leyden Jar.—In all our previous experiments we have allowed the electricity produced to pass off in the shape of sparks. We shall now describe the means used for the purpose of producing great mechanical, heating, and other effects. By means of a Leyden jar of large size we can even imitate thunder and lightning, and destroy, ignite, and melt a large variety of objects with great ease.

The Leyden jar is so called from its use having been discovered in a town of that name in Germany. One of its discoverers, M. Muschenbrœck, had a most unexpected introduction to its effects, by a powerful shock which he received, and which so terrified him that he said he would not take another shock for the whole kingdom of France. Our young friends need be under no such alarm, as we have repeatedly given and taken shocks of much greater force than that gentleman received; and the only result we have observed has been the laughter of our friends at the ugly face we made, and the sensation of a momentary pain on our own part.

Experiment 36.—*To make a Leyden Jar.*—Half fill a thin, round, white glass medicine bottle, holding about half a pint, with clean iron or brass filings, and to the end of a wire, long enough to reach to the bottom of the glass and to project three inches above its neck, fix a cork neatly covered with tinfoil; this wire should be forced into the iron filings, and the cork should be so covered with tinfoil that the foil may completely touch the wire with which it is connected. Outside of the jar paste some tinfoil half-way up and all round the bottle; the jar will then appear as in fig. 15.

The above will form a neat and efficient single Leyden jar, and if our reader makes six of these, and connects all their knobs together by a wire, and all their outsides by another wire touching the tinfoil of each, he will form what is called the Leyden battery, an arrangement which will be required for some of our experiments.

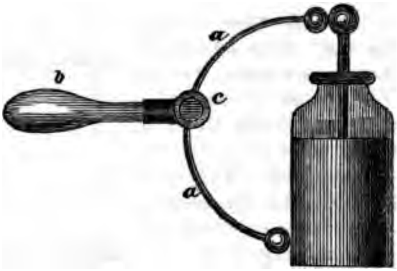


Fig. 15.

Another mode of making these is by lining the inside and outside of a wide-mouth jar with tinfoil, and instead of the wire, cork, and tinfoil knob, a wire and chain, a neck of wood, and a brass ball are used. Either form will do, but our young friends will find the one we have described can be made for sixpence, whilst those of the same size sold in the shops would cost seven times as much. Fig. 16 represents a Leyden battery.

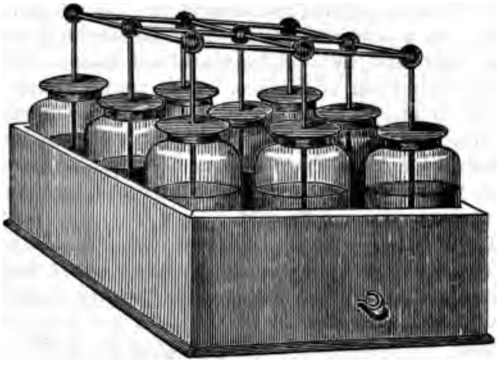


Fig. 16.

You will require another instrument, called a discharger. This is easily made by bending a piece of thick brass wire into a curved form, and at each end must be either a brass or tinfoil knob. In the middle, fix a gutta-percha tube, eight inches long, to serve as a handle. Fig. 15 at once explains the construction of this instrument, where it is marked *a*, *b*, *c*.

Experiment 37.—*To charge a Leyden Jar.*—Present the ball to within half an inch of the conductor of the machine, whilst an assistant turns the handle. The outside of the jar may be held in the hand, and a wire from a gas-pipe should be held in contact with it. Sparks will pass from the machine, gradually diminishing in number and noise. Do not hold the knob too long to the conductor, as you may overcharge the jar, and it will perhaps discharge itself, and may even be broken. An inspection of fig. 17 will enable you to understand the proper mode of conducting this experiment.

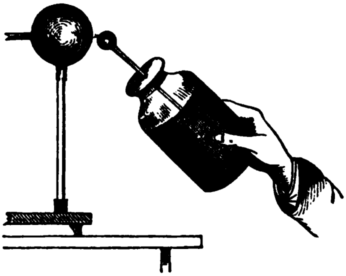


Fig. 17.

Take care that the jar is dry, warm, and free from dust, and do not let the hand extend beyond the tinfoil cover whilst you are charging.

Experiment 38.—*To discharge a Jar.*—Place one ball of the discharger (see Experiment 36) on the outside tinfoil coating of the jar, and bring the other ball near to the ball of the jar. A bright spark will pass, a loud noise will be heard at the same time, and the jar will be thus discharged. Fig. 15 illustrates the plan here explained.

Experiment 39.—*To obtain a Shock from a Charged Jar.*—Instead of the discharger, place one hand on the tinfoil covering, and bring the other to the ball of the jar. Just as the hand touches the knob, a strong shock will be felt across the chest and arms. It is better to touch both the outside and ball with a wire held in the hands, as the shock may cause you to drop the jar if you were holding it.

Experiment 40.—*To give a Shock to a number of Persons.*—Let them all join hands, and to the first give a wire, which you have already attached to the *outside* of the jar. Place another wire in the hands of the last person, and attach this one to the brass wire of your discharger. Now bring the ball of the discharger into contact with the ball of your charged jar. Every one will experience a shock at the same moment, whilst you will escape by holding the gutta-percha handle.

Fig. 18 illustrates the best mode of giving an electric shock to a number of persons.

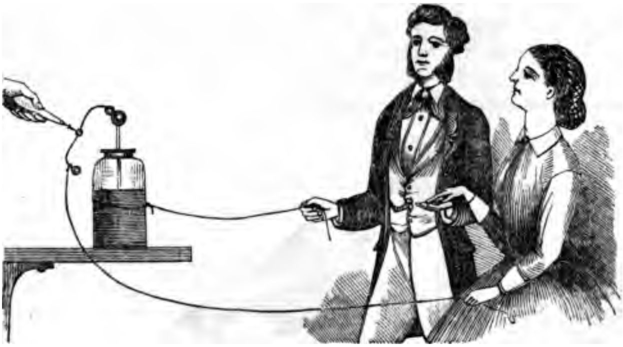


Fig. 18.

Do not bring *both* balls of the discharger into contact with the jar, inasmuch as the circuit must be completed through the bodies of those receiving the shock.

EXPERIMENT 41.—A jar cannot be charged when insulated, or unless its outside is in connexion with the earth. Place a jar on the glass-legged stool (see Experiment 21), and then bring its knob near the conductor. After working the machine for some time apply the discharger, as in Experiment 38, and you will get no spark. Now connect the outside of the jar with the earth, and again work the machine. You will find that the charge enters the jar now, as before in Experiment 37, and may be discharged afterwards in the usual manner.

EXPERIMENT 42.—*To charge a Jar by means of the Electrophorus.*—Having excited the resin-plate by means of a dry, warm flannel, place on it the metal cover, holding it by the handle. Touch the top of the cover, and now present its edge to the knob of the Leyden jar. Repeat this process a few times, omitting only the rubbing of the resin with the flannel, and the jar will be charged. (See fig. 19.)

This forms a very simple way of obtaining shocks, and at the same time at little cost, as the electrophorus, already described, and the jar, together need not cost more than two or three shillings, and by being kept dry and free from dust they *are always* ready for use.

Experiment 43.—Discharge a jar through a brass or iron chain. If the chain is made a few feet in length, and attached to the earth at one end and to the brass knob of the discharger at the other, on being presented to the jar a beautiful series of sparks will be produced at every break between the metals.

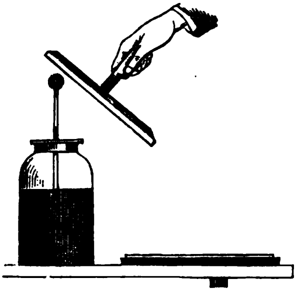


Fig. 19.

Experiment 44.—*The Thunder House.*—Construct a small cottage, in wood, tin, or zinc, through the top of which pass a brass wire, divided in the middle of the house. The upper end of the wire should be fitted with a brass ball, and the lower end connected with the earth. You must prevent the upper wire from touching the material of the house, by enclosing it in a glass tube. Attach to the end of the earth-wire, and about a quarter of an inch under the upper one, a small cup, into which ether is to be poured. On connecting the lower wire with the outside of a charged jar, and bringing the end of the discharging-rod in contact with the upper wire and the knob of the jar, the discharge will take place, and set fire to the ether in the house.

Experiment 45.—Instead of the brass ball mentioned in the last arrangement, make the top of the wire pointed. You will now not succeed in inflaming the ether in the cup, because the point will diffuse and allow the whole of the electricity to pass off.

Experiment 46.—Replace the brass ball, and allow the upper wire to rest on the cup, so as to make a continuous connexion with the outside and inside of the jar during the discharge. If you now fill the cup with ether, and discharge the jar, you will find that the ether will not ignite, owing to the conducting-wire being continuous. It is on this principle that lightning-conductors are constructed.

LIGHTNING CONDUCTORS.

Our young friends, on carefully repeating these experiments, which we have intentionally arranged in the above order, will be enabled at once to understand the use of what are termed lightning-conductors. In Experiment 44 we observe, that if the conducting-wires were divided, the ether was ignited. In our last, we found that on making a *continuous* conductor, the whole of the force passed off without producing the least effect. The very same result is observed in daily life. If a church-steeple, a tall chimney, or the masts of a ship, are thus provided with conductors, which are either iron or copper rods, half an inch thick, and pointed at the upper end, and buried in the earth at the lower extremity, the most severe thunderstorms pass over places so protected without doing the least harm.

We are indebted to Franklin for many valuable discoveries in electrical science; in fact, we may almost call him its father. But we must not forget here another eminent man, Sir W. Snow Harris, who has, by applying conductors to ship's masts, been the means of saving the lives of perhaps thousands of our brave seamen.

The electrical kite may be here mentioned. Franklin was enabled, by means of a common kite, to prove that electricity was the cause of thunder and lightning, and lately Mr. Crosse, of Broomfield, near Taunton, has erected a large number of iron rods, and by means of these he has been enabled to bring a thunderstorm into his house, and to witness the most fearful effects of large quantities of electricity. These experiments are of the most dangerous kind, and one gentleman, in repeating some of them, was killed instantaneously. We conclude our remarks on this subject by warning you of the danger of flying even common kites in cloudy weather, for, although the string employed may be a bad conductor, still, if it is wetted by rain, its conducting power is greatly increased, and it may, thereby, become a source of great danger to you, and even possibly result in death. The writer once received a severe shock whilst electrical kite-flying in comparatively safe circumstances; and thus warns his young friends to refrain from such dangerous attempts.

EXPERIMENTS WITH THE ELECTRIC BATTERY.

As we have just alluded to the effect of lightning, we shall *instruct you* how to produce the same results on the small scale by means of a number of jars combined together. Of course the length and thickness of the wire, &c., melted and destroyed, will depend upon the size of the Leyden jars you employ. We shall suppose that you have combined together six; each being about eight inches high, and four in diameter. Take care that every part is perfectly clean, dry, and slightly warmed. All their outsides are connected together by means of tinfoil or wire, and joined to the earth by another wire, and all their insides must be joined by twisting one wire round each, just underneath their brass knobs.

In fact, this battery arrangement amounts to nothing more than making six jars, electrically speaking, equal in size to one jar, presenting an equal capacity. You may connect a number of these batteries, and so increase the effect providing your electrical machine is large enough to charge them all.

Experiment 47.—Connect six jars together, and attach to the end of one a wire ending in a brass knob placed close to the conductor of the machine; and having joined all the outsides of the jars together, let the wire extend to the earth. When charged, discharge them by means of a discharging-rod as before explained. The spark and noise produced will be much more powerful than that from a single jar.

Experiment 48.—Draw a line by means of a quill pen, filled with gum-water, on a sheet of white paper. On this, spread some gold, silver, and Dutch-metal leaf, in separate lines, at two inches apart each. (See fig. 20.)

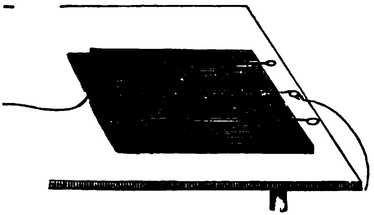


Fig. 20.

Let this paper be well dried at the fire, then brush off the superfluous metal-leaf, and pin at its four corners the sheet of paper, on a dry piece of pasteboard. Now connect the wire from the outside of the battery with one end of the gold-leaf, and place a brass ball on the other end of the leaf. When the battery is charged, attach a wire from its outside to one end of the leaf, and by means of the discharger, connect the inside of the battery with the brass ball. A bright spark will pass, and the whole of the gold-leaf will be destroyed with a loud report. Proceed with the remaining leaves in the same way, and observe the difference of the colour of the light produced and the marks made on the paper.

This illustrates a common occurrence to persons struck by lightning. In such cases, metals, such as coin and watches, have their edges fused without setting fire to the pockets which contain them; and in our experiment, the paper will be deeply stained by the oxide of the metals, and yet will not be ignited, although an intense heat has been produced.

Experiment 49.—*To ignite Gunpowder.*—Place on a plate a little gunpowder, and on each side of it and touching it, fix two wires; one of these wires attach to the outside of the battery; to the other tie an inch or two of wet string, the other end of which is attached to the discharging-rod. When the battery is charged, present the other end of the discharging-rod to the knob of the battery, and the gunpowder in the plate will inflame. (See fig. 21.)

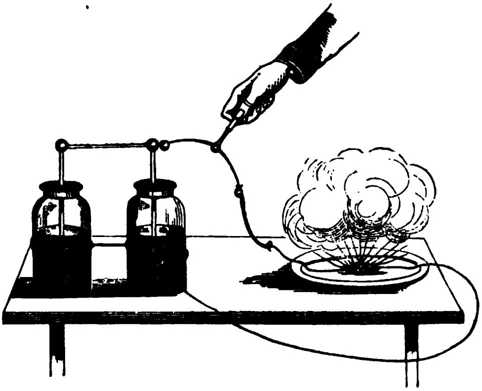


Fig. 21.

Experiment 50.—Replace the wet string in the last experiment, by fixing a metal wire to the discharger, and so forming a continuous connexion. The powder on the plate will be thrown about, but not inflamed. The object of the string is thus to check the electricity in its flow, and so to educe its heating, instead of its mechanical, effects.

Experiment 51.—*To break Glass and to drive Gold-leaf into it.*—For this purpose you will require two pieces of thin window-*glass* carefully cleaned and dried. Through their length stretch a piece of gold-leaf, an eighth of an inch wide, and tie the pieces of glass together by means of silk thread. Let the leaf stretch half an inch beyond the ends of the glasses, which, for your size of battery, may be four inches long and an inch wide. Attach one end of the leaf to the outside of the battery, and on the other place a small brass ball, and let the whole rest on two dry glass tumblers, as represented in fig. 22. Now connect the brass ball by means of the discharger with the charged battery; a powerful explosion will take place. The glass is generally broken in pieces and the leaf driven into its pores, forming at times a very pretty appearance. Take care that the glass does not fly into the eye or face, as it is broken into very sharp pieces, and thus is very dangerous. This experiment is generally tried on a stand made for the purpose; but this is an expensive piece of apparatus, and our plan will succeed well if proper care is taken. A modification of this electrical press we shall explain under the head of Voltaic Electricity.

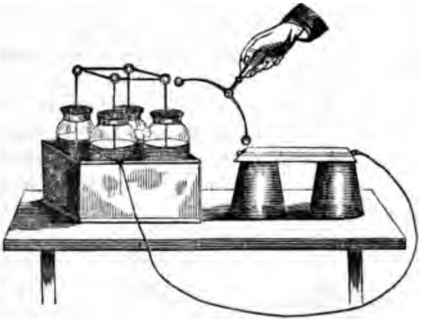


Fig. 22.

Experiment 52.—*To light a Gas Lamp.*—Attach the jet to the outside of the battery, and bring one knob of the discharger in contact with the inside of the battery, whilst its further knob is held within a quarter of an inch of the gas-jet. If the gas is escaping, it will be immediately lit by the spark.

Experiment 53.—A candle newly blown out, a piece of phosphorus, ether, &c., may easily be set on fire by similar means.

Experiment 54.—Stretch a very fine piece of iron wire between two pieces of glass tube. One end of the wire is to be connected with the outside of the battery; and a brass ball placed on the other tube touching the fine wire. Now bring the discharging-rod to the brass ball, so as to cause the current to pass through the wire from the battery. The wire will be melted into globules. Wire for this purpose may be obtained of any watchmaker.

Experiment 55.—*Luminous Eggs.*—String four eggs, from which you have taken out the contents, on to a chain formed of alternate links of copper wire and silk thread. This is done by passing a piece of wire through each end of the shell, and fastening the wires together by means of a silk thread, leaving about a quarter of an inch between each wire inside the shell; arrange all the egg-shells thus, and attach the last wire to the outside of the Leyden jar. Now by means of the discharger send a charge through the wires and shells. Each will become luminous, and they will present one of the prettiest experiments in electrical science. If your machine is a powerful one, you may hang the string to the conductor, attaching the lower wire to the earth. The illumination will continue so long as the machine is in action. Fig. 23 represents the arrangement.

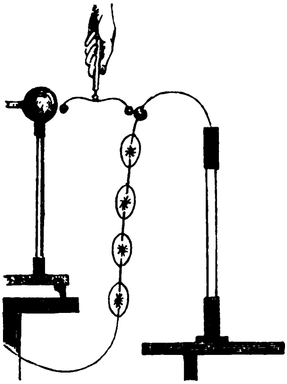


Fig. 23.

Experiment 56.—*The Diamond Leyden Jar.*—Instead of making the inside and outside coatings of the Leyden jar continuous, form them of pieces cut into a diamond shape, and separated to a short distance from each other. When the jar is charged and discharged, flashes of light will pass between every interval of the pieces of tinfoil, presenting a brilliant appearance.

In the foregoing experiments we have endeavoured to introduce those most likely to acquaint you with the leading characters of electricity obtained by friction, and have thus considered the spark, electrical attraction and repulsion, together with the accumulation of electricity by means of the Leyden jar and battery. We might easily have mentioned many more experiments, but as a considerable quantity of apparatus would be required to carry them out, we have refrained from so doing.

Before concluding our remarks on this branch of electrical science, we will give you some description of a very singular form of electrical machine, by means of which we are enabled to obtain an immense amount of electricity from steam.

THE HYDRO-ELECTRIC MACHINE.

The largest instrument of this kind yet constructed is that in the London Polytechnic, Regent Street. Having often experimented with it in electrical lectures at that institution, we will endeavour to give you an idea of its construction and of the effects it produces, referring you to the head-piece of this section (page 89) in which

A A represent the boiler, which is six feet long and three feet in diameter. The furnace is placed in the centre of the boiler.

B B are six glass legs on which the boiler stands.

C is a square box into which the steam rushes when the machine is in action. This is furnished with a large number of metallic points.

D D are two handles by which the steam is turned into the bent pipe on the top of the boiler.

T is a row of forty-six bent pipes, each of whose ends is formed of a piece of partridge wood, constructed very much like the shape of the common bat's-wing gas-burner. Through these pipes the steam in passing is partly condensed, and the water thus formed produces electricity by its friction against the wood jets just mentioned.

The pressure of steam we usually employed was ninety pounds on the square inch. We have tried it with from sixty to one hundred and twenty pounds' pressure, but have always found that of ninety pounds gave the best effect.

The spark produced on a dry cold night, especially during frosty weather, is from eighteen inches to two feet long, and apparently an inch wide. Its colour is a deep blue, and, like a flash of lightning, it rushes through the air in a zigzag form.

The spark may be sent over a chain of alternate pieces of tinfoil and glass beads through a length of over 100 feet, every break in the chain giving a separate spark.

The experiments with eggs, tinfoil, spots on glass, and others we have described in our previous pages, are effected in the most brilliant manner.

A Leyden jar two feet high and four feet in circumference can be made to charge and discharge itself many times in the course of a minute. The spark is very vivid, and the noise most deafening.

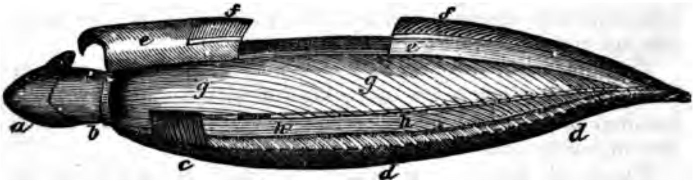
By means of a Leyden battery of twenty-four jars of the above size, we have melted and dispersed five metal wires nearly two feet long, and the experiment of breaking glass succeeds with pieces eighteen inches long, and having slips of gold-leaf between them of an inch in width.

The above results will give you an idea of the enormous power of this machine.

We should here mention that the two largest glass plate-machines yet made are, one at the Polytechnic, whose plate is seven feet in diameter, and the other of ten feet in diameter, which was some years ago in daily use at the Panopticon, Leicester-square. Neither of these, however, gave any effects equal to those we have described as produced by the hydro-electrical machine; and we may add that a spark two inches long from the latter instrument was sufficient to knock down the person receiving it.

In concluding our remarks on frictional electricity, we must call your attention to the fact that some kind of fishes are able to give powerful electric shocks. One of the best known of these is the Gymnotus, of which we append an engraving, showing the nerves, &c., by which the electricity is produced. One of these was exhibited some years ago at the Polytechnic, Regent-street.

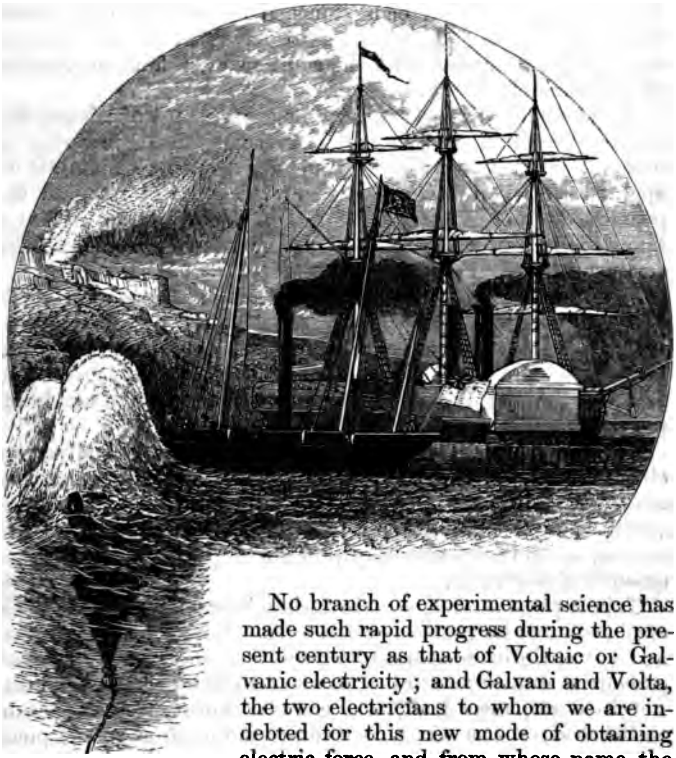
Fig. 24.



SECTION OF THE GYMNOTUS.

In the above, *a* represents the head; *b*, the cavity of the body; *d d*, the ventral fin; *e e*, the skin; *f f*, the muscles of the fin; *g g*, the electrical organ; and *h h*, the smaller organ. We thus observe that electricity is to be obtained from every imaginable source.

EXPERIMENTS IN VOLTAIC ELECTRICITY.



No branch of experimental science has made such rapid progress during the present century as that of Voltaic or Galvanic electricity; and Galvani and Volta, the two electricians to whom we are indebted for this new mode of obtaining electric force, and from whose name the science has been called, would be astonished if they were now to observe the extensive application of the voltaic battery, employed as it is from the plating of our household utensils to the conveyance of our thoughts instantaneously to the very ends of the earth.

In dealing with this interesting subject, we shall first describe the mode of constructing voltaic batteries. We shall then mention the various effects produced by them, including those of heat, light, and magnetism. We shall also explain the chemical effects of the current of electricity, and give you full directions for pursuing the process of electrotyping, plating, and gilding.

This branch of science seems to have had its origin in an accident. The story usually told is, that Galvani, being engaged in electrical experiments, noticed that the legs of a frog were agitated on being touched by two different metals when in contact. This seems to have led to the idea of employing two metals, with the addition of a fluid, as a means of procuring electricity.

Accidents of this sort happen to every student of science, but it is only from those who are possessed of an acute power of observation that we obtain valuable results. Thousands of apples have fallen in the course of time, but it required the penetration and observant genius of a Newton to deduce a knowledge of a great law of nature from one of the most common of natural occurrences.

We shall proceed to describe the construction of a small battery, and also of one which will enable our young friends to try all the experiments in connexion with this fascinating and brilliant science. We shall not require expensive apparatus; in fact, by attending to our instructions, you may make nearly all the apparatus you require yourself.

EXPERIMENT 1.—By placing a piece of zinc and silver on either side of the tongue, and causing them to touch, a peculiar sensation is produced. Extending this simple arrangement, and substituting a little acid and water for the moisture of the tongue, we can form a battery which will give off a considerable amount of electricity.

Take a piece of zinc, say six inches long and an inch wide, amalgamate it by rubbing over it a little mercury and some acid and water, till it assumes a highly polished appearance, and then place it in a tumbler filled with water, to which you have added a little sulphuric acid. The mercury will prevent the action of the acid on the zinc. Now dip into the same glass a piece of copper or silver of the same size; the whole will remain without action. If, however, you bring together the top or bottom edges of the two metals, the water will be immediately decomposed. Hydrogen gas will pass from the copper or silver surface, and at the same time a galvanic battery producing electricity will be formed.

EXPERIMENT 2.—You may vary the experiment by twisting round or soldering on each plate a piece of copper wire. No action takes place till the wires from each plate touch each other, and then a current of electricity passes from the zinc, through the water, to the copper, and back to the zinc, by means of the joined wire, as indicated by the arrow in the next engraving, fig. 1, where *c* represents the copper, *z* the zinc *plate, and w the* wire connecting the wire.

We do not use a strictly philosophical expression by saying "a current of electricity passes, &c.;" but as no inconvenience results therefrom, and as great facility arises from using these terms, we shall employ them in all our future remarks, leaving our young friends to arrive at more accurate ideas, when they become advanced students. We have been sometimes asked in our lectures to break the wire coming from the batteries, so that persons might see the "electric fluid" run through them. In fact, some people seem to have the idea that electricity is, like gas and water, conveyed in pipes; but our young friends will bear in mind that these phrases are used for the sake of simplicity, and their experiments will soon correct erroneous impressions arising from the use of incorrect terms.

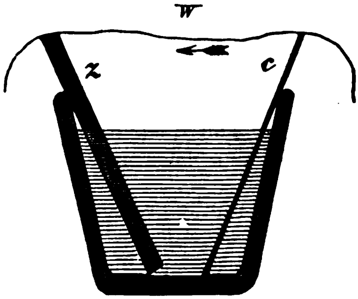


Fig. 1.

Experiment 3.—The effect of the electricity thus produced may be made evident by placing the ends of the wire on each side of the tongue. The same sensation will be observed as that named in Experiment 1.

The arrangement in Experiment 2 is called a *cell* of the voltaic battery, and the plates are thus named:—

The zinc plate is called the positive plate.

The copper plate is called the negative plate.

The *ends* of the wires acquire opposite electrical states, and have different names to the plates, from which they proceed thus—

The extreme end of the wire from the zinc is called negative.

The extreme end of the wire from the copper is called positive, these ends being termed *poles*.

We content ourselves here with naming these, and shall give our reasons when we introduce chemical experiments with the battery.

GALVANIC BATTERIES.

Experiment 4.—We shall now give instructions as to the construction of different galvanic batteries, beginning with the Pile. To make one of these, obtain from the tin-smith twenty pieces each of copper and zinc, and cut up twenty pieces of flannel or brown paper. The thickness is of no consequence, but the size of each of the plates and paper should be about two inches square.

Amalgamate the *zincs only* by proceeding as in Experiment 1. You may then dip the pieces of flannel or brown paper in some water, to which one-tenth part in bulk of sulphuric acid has been added. As soon as these are thoroughly wet, press them together until all the water is removed that will drain off, and proceed to the construction of the pile.

On a piece of wood place, first a zinc plate, to which you have soldered or fixed a thin copper wire, say a foot long; on the zinc place a piece of copper, then a piece of wet paper, then zinc, copper, paper, and so on until the whole of the pieces are piled up in the order we name. Take care to have one piece of copper left at the top, and to this a wire should be soldered. Fig. 2 illustrates one of these piles, in which the letters represent the successive arrangement of the metals and cloth. We only exhibit eight sets of the series, which, however, is quite sufficient for the purpose of showing its construction.

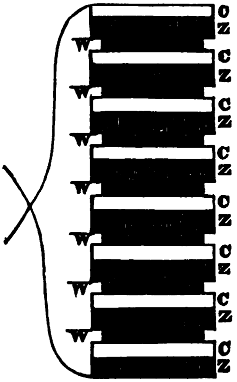


Fig. 2.

Experiment 5.—On bringing the two wires together, and then separating them, you will observe a bright spark pass; and if, instead of twenty pieces, you employ about fifty, you will experience a smart shock on holding the two wires in your hands, if they have been previously wetted with a little salt and water.

To keep the pile from falling, you can easily fix two or three sticks in the wooden foot. But as this is an inconvenient form of arrangement, we only introduce it for the purpose of showing you the sort of battery first used, and as a very cheap mode of starting your experiments in the science. *The whole affair* need not cost above two shillings, as old copper and zinc, cut into pieces, and cleaned by sand-paper before use, will answer the purpose.

The next improvement effected was to solder the plates of zinc and copper together, and to fix them by means of cement in a long wooden box. Dr. Wollaston increased the power of the battery by doubling the sheet of copper round the zinc. Acid and water were used round the plates, instead of the wetted paper employed in the pile, and the plates were hung in a trough containing the exciting liquid. One of these arrangements is represented in fig. 3.

Dr. Daniell, of King's College, London, invented an excellent arrangement, which has the advantage of being constant in its action. The pile and other such batteries begin to lose their power almost immediately after being set in action, whereas the constant battery will last for hours, and give off a continuous and equal supply of electricity. As we consider this one of the best forms of battery for electrotyping, we shall instruct our young friends how to make one which will serve well for that purpose.

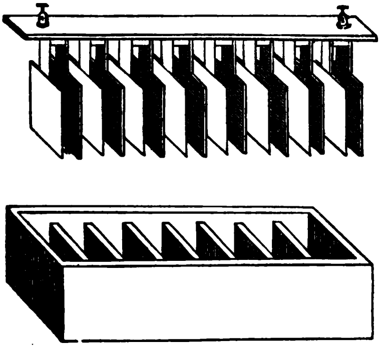


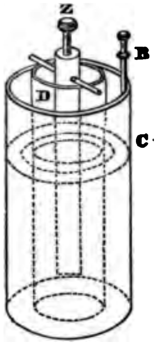
Fig. 3.

Experiment 6.—Procure a piece of sheet copper, ten inches long and six inches wide, and at one end have soldered a wire, about eighteen inches long—common bell-wire will do.

The copper is now to be bent round, to form a cylinder six inches high and three inches in diameter. Place this in a stone or glass pot of the same height. Inside the copper cylinder place a porous pot, six inches high and about an inch and a half in diameter. If you cannot obtain one of these (they are sold in every one of our large towns for sixpence each), roll round a roller two folds of stiff brown paper; into the end of the cylinder so formed tie a cork, so as to make one end water-tight, and to prevent the paper opening out; cement the edge with a very narrow strip of melted cobbler's wax. Into this porous pot a piece of zinc seven inches long and one wide must be placed, to which a wire eighteen inches long has been soldered. The zinc must be amalgamated. (See Experiment 1.)

Fig. 4 represents a similar arrangement, with the exception that the copper is made to hold the liquid instead of using an outer pot for that purpose.

Fig. 4.



C is the copper vessel, to which B, a binding-screw, is attached.
D is the porous tube, and Z is a zinc rod suspended inside the porous pot D.

To charge this battery, a strong solution of sulphate of copper in water, to which has been added 1-8th of its bulk of sulphuric acid, must be poured into the outer pot *next the copper*. *Into the inner pot*, where the zinc is, pour water, with 1-10th of its bulk of sulphuric acid. Take care to make no mistake with reference to these solutions. If you require, as in electrotyping, to keep this battery long at work, you must hang in the copper solution some crystals of sulphate of copper, and keep up a supply, as they gradually dissolve away. The charge of acid in such case need not be so strong in the solution next the zinc. In some instances a solution of common salt will answer very well in electrotyping.

Experiment 7.—On connecting the two wires of this constant battery, you will find no hydrogen given off from the copper. *It is all employed* in decomposing the copper salt. If, after keeping the wires connected for two or three minutes, you remove the copper plate, you will find that its surface is beautifully coated with pure copper, obtained from the solution by galvanic action. In our future remarks we shall call this a Daniell's battery, although it is a modification of his first plan.

Experiment 8.—The next battery we shall describe is that invented by Mr. Smee. It is a very convenient one, and requires but one liquid to charge it. It is made by doubling a piece of zinc, which is afterwards amalgamated, round a sheet of pure silver, whose surface has been first coated with platina in the form of a fine powder, by holding the silver for a short time in a solution of chloride of platina. The arrangement is then immersed in a mixture of ten parts of water to one, by bulk, of sulphuric acid, and during the action of the battery hydrogen is given off from the silver surface. These batteries are sold by the operative chemists, &c., at prices varying from five shillings upwards.

Experiment 9.—The most powerful arrangement yet invented, is that by Professor Grove, and this is the sort of battery we would advise you to construct for the purpose of obtaining the electric light, melting of wires, and other such experiments; for whilst the Daniell's or Smee's battery is the best for use as a *single cell*, Grove's battery is the best for a *combined series.*

To make a Grove's Battery.—Procure twenty gallipots, two inches high (worth about a penny each), and as many bowls of large tobacco pipes. The latter must have the small hole at the lower end stopped up by means of plaster of Paris, and a kind of stand made of the same material, to support the bowls upright, as seen in fig. 5. It is as well to keep a few of these simple porous pots by you, in case of accident to those in use in the battery, so as easily to replace any that are broken. You can purchase pots of the kind at the instrument-makers for about three-pence each. Have cut by a tin-smith, twenty pieces of zinc six inches long and two inches deep (see fig. 6). The long, thin strip may either be cut from the sheet or be a piece of copper soldered on the zinc; it should be four inches long and half an inch wide, as in No. 1. The sheet must be then bent into the form of a cylinder, as at No. 2; and the copper or zinc strip is so bent as to form a curve, as at No. 3.

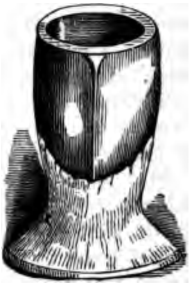


Fig. 5.

The zinc, when bent into form No. 3, must be amalgamated.

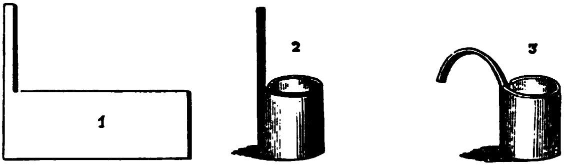


Fig. 6.

You must now solder on to each of nineteen of the zincs a piece of platina, a quarter of an inch wide and two inches long. This is easily done by wetting the end of the copper strip with a little muriatic acid, and then dipping it into a little soft solder melted in a ladle. Some of the solder will adhere to the copper, and by now holding it in the flame of the spirit-lamp, and placing the edge of the platina with it in the flame, the tin will melt and the platina will adhere, and must be allowed to cool. The whole, when finished, will appear as in fig. 7.

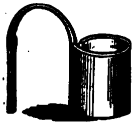


Fig. 7.

By this easy plan all your connexions are complete without binding-screws. To one zinc, and to one platina (the twentieth of the series) a copper wire of No. 16 gauge, and 30 inches long, must be soldered. These will form the last plates of the series, from each of which the wires will serve to conduct the electricity.

The next step is to put the battery together. You must first fill each of the tobacco-bowls with strong nitric acid, and place them in the centre of each gallipot. Take care not to spill the acid over into the outer pot, as that would speedily destroy the zincs. Then place the zinc cylinder to which the wire is attached, in the first pot; and in the second put another cylinder of zinc, with its platina immersed in the tobacco-pipe bowl of the first one, the platina of the third zinc in the bowl of the second pot, and so on throughout the series.

Having thus arranged that the platina of each zinc shall dip into the bowl of the pot immediately preceding it, on arriving at the last pot, the platina, with the wire attached, must be placed in its bowl, and the wires kept steady by driving into a board two nails, round which each of them should be twisted, but kept separate.

The outside pots, containing the zincs, should each now be *filled with sulph*uric acid and water, in the proportion of one of the former to eight of the latter; the mixture being cooled before it is poured in.

The general arrangement of a galvanic battery, ready for action, is seen in fig. 8, where six cells of Smee's arrangement (see Experiment 8) are represented with conducting-wires, &c., ready for experimenting with. Your battery will now be complete; and on bringing together, and then separating the two ends of the wires proceeding from the zinc and platina, you will perceive a brilliant green light, which will dazzle the eyes.

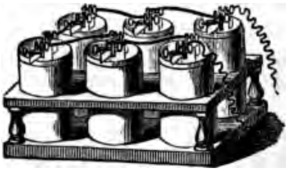


Fig. 8.

The platina is the most expensive part of our arrangement; but if you purchase a piece, two inches wide and six inches long, of Messrs. Johnson and Matthey, of Hatton Garden, London, or of the philosophical instrument-makers, which will cost you about seven shillings, it will be about the size you require for the twenty, allowing for irregularities in cutting the separate pieces from it. You will require two other pieces of platina-foil, each two inches long and an inch wide, for other experiments.

The battery described will melt ten inches of thin iron wire; will give a spark between charcoal points one-eighth of an inch long, and afford you an opportunity of trying every experiment of which we speak in our future progress, in the most satisfactory manner, and with as good an effect as you will generally witness at the lecture-table. The total cost of the battery should not exceed fifteen shillings.

Four of these cells are sufficient for most of our experiments, if on the small scale; but we recommend the series of twenty, as affording you the opportunity of carrying out your trials in a satisfactory and effectual way.

On concluding your experiments with the battery, let every part be well washed with abundance of cold water. It is better to employ fresh acids each time, as the cost is very slight, and you will thus ensure success.

The object of using nitric acid next the platina, is to get rid of the hydrogen. This gas, instead of being given off as in Smee's, combines with the oxygen of the nitric acid, and forms water.

Experiment 10.—There are many modifications of Grove's battery, such as Bunsen's carbon battery, in which the platina is replaced by a charcoal plate. A piece of cast iron will also do instead of the platina; but eventually, when the nitric acid becomes weak, it acts on the iron, and the arrangement is destroyed. We have even used a plate of copper as the negative metal, and for a few moments the action is equal to that of platina. The acid then acts violently on the copper, the nitrate of which is formed, but afterwards the action is pretty constant for some hours. During the experiment, the strange fact is exhibited of the metal most acted on still remaining negative. In all other batteries the zinc is the only one dissolved away; and in Grove's battery, which we have recommended you, the platina, if taken care of, will last for years.

A very interesting arrangement was invented by Professor Grove, called the gas battery. In fig. 9, representing one of these, we have four pots, in each of which two tubes are placed. These tubes contain a piece of platina-foil, which is melted by the blowpipe into the top of the tube, leaving a small piece outside of each. One tube in each pot is filled with oxygen, and the other with hydrogen; and the platina of the oxygen tube of one pot is attached to that of the hydrogen tube of the next: the pots themselves are half-filled with sulphuric acid and water. This interesting arrangement produces electricity during the *composition* of water, instead of during its decomposition, as is the case in all other batteries. After some time the water rises in the tubes, which is owing to all the gas being used up.

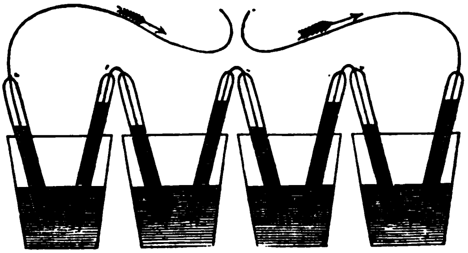


Fig. 9.

EXPERIMENTS WITH THE VOLTAIC BATTERY.

Having explained to you the mode of constructing and charging batteries, we now proceed to the experiments which *may be made* by one of the kind we have described.

Experiment 11.—Join the ends of the copper wires proceeding from the battery by means of a fine iron or steel wire. The wire will be at once melted into globules.

Experiment 12.—Repeat this with a platina wire. The wire will become white-hot, and remain so as long as the battery continues in good action.

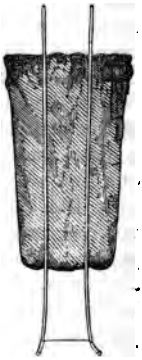


Fig. 10.

Experiment 13.—*To blow up Gunpowder under Water.*—Fill a cartridge with some gunpowder, and outside this tie a small bladder, so as to prevent the water entering and wetting the powder. Insert into a cork that will fit the neck of the cartridge two wires, which should project through the cork, say two inches, as in fig. 10. Into the cartridge containing the powder fix a piece of fine iron wire, crossing the two wires protruding through the cork. The cork and wires are to be fitted into the neck of the cartridge, so as that the fine wire joining the thick ones may be in the centre of the powder. The thick wires (No. 16 gauge) should be long enough to reach from the cartridge to the place where your battery is. Make the neck of the cartridge water-tight, by means of a little cobbler's wax. When all is ready, sink your cartridge to the bottom of a pond or large tub, and take care that the thick wires do not touch each other in any part. Attach one of the wires from the

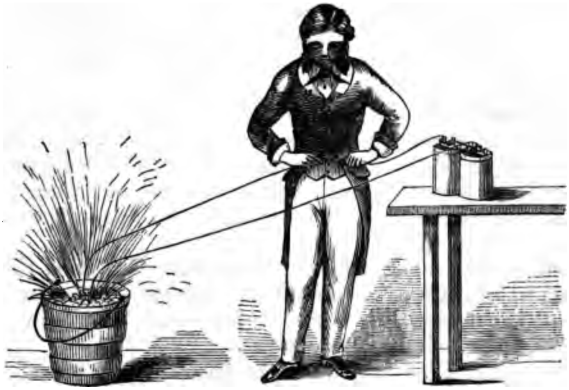


Fig. 11.

cartridge to one end of the battery, and when ready touch the other end of the battery with the other wire. The fine wire in the cartridge will now be melted, and the powder will instantly explode.

The entire arrangement will be understood by carefully studying our illustration, fig. 11.

EXPERIMENT 14.—In one of our earliest experiments we tried blowing up gunpowder in a water-butt. The result was most satisfactory, except in one respect, and that was that we succeeded in blowing the butt to pieces. We once saw a lecturer attempt to illustrate this experiment by blowing up water in a pail, and he succeeded in completely drenching the directors of the institute. Instead of gunpowder place some blue fire on a plate, and ignite it by means similar to what we described in our last experiment. Let the fine wire lie on the top of the blue fire, on which you have sprinkled a few grains of gunpowder, and presuming you are trying the experiment in a garden, bring your long wires from the plate to the battery, and on making the connexion, the blue fire will be ignited.

The Russians employed a similar arrangement to this, for the purpose of exploding one class of their infernal machines, off Cronstadt. A vessel holding gunpowder was sunk in the supposed track of our ships: the wires, covered with gutta-percha, stretched to the shore, and when our vessel was just over the infernal machine, the battery connexion was completed, and the machine blew up. These, however, did no damage on any occasion, owing to the great resistance of the water. The head-piece to this section (page 115) will give you an idea of the mode in which these machines were arranged and employed.

EXPERIMENT 15.—*To light Gas by Voltaic Electricity.*—Fix two wires in a cork, and stretch a fine wire across them, as before; tie the cork to the burner, so that the fine wire shall rest just over the jet. On turning on the gas and making connexion with the battery, the melting of the fine iron wire will ignite the gas at once.

EXPERIMENT 16.—A very convenient way of keeping the conducting wires apart up to where the fine wire is joined on them, is to cut two slits in a cork on opposite sides. Put the wires in the slits, and tie them tightly with string.

EXPERIMENT 17.—The reason the fine iron wire melts is, that it is too small to carry the whole of the electricity passing, owing to its resistance. Again, good conductors will not melt, for the same reason. To illustrate this, make a chain of thick copper or silver wire, and of fine iron wire in alternate pieces.

Now bring your batteries in connexion with the two ends of the chain, and all the fine wire will be melted and leave the thicker ones untouched. You may vary the experiment by nailing thick copper wires to the edge of a board, and joining them by means of fine iron wire, as represented in fig. 12.

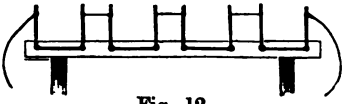


Fig. 12.

Experiment 18.—*To boil Water by Galvanism.*—Into a glass tube, four inches long and about a quarter of an inch wide, fix a cork at each end, through which two wires should project about an inch each. Join these two, by means of a fine iron wire, and fill the tube with water. Apply the wires from the battery to the thick ones, and the heat from the fine wire will soon boil the water inside the tube.

A slit should be made in one of the corks, to allow of the expansion of the water and the escape of steam, and the tube should be held aslant with the slit end up.

Experiment 19.—*Another Way.*—Make a little coil of fine iron wire, and fit this to the thick wire. Dip the coil in a small glass of water, and connect with the battery, as represented in fig. 13.

The writer was once lecturing on this subject, and trying this experiment with a very powerful battery. Of course the water soon boiled. At that time it was proposed to send steamers to Australia and India, but the great objection raised was the enormous expense of the coal. A gentleman present, observing the success of the experiments, suggested, much to our amusement, that galvanism might be employed for the purpose of producing steam. We may just remind our young readers that it would cost some shillings to boil off a *wine-glassful* of water by these means, and we shall leave them to calculate the cost of boiling off the *tons* of water required to produce steam sufficient for driving two engines of 500-horse power each, for two or three months.

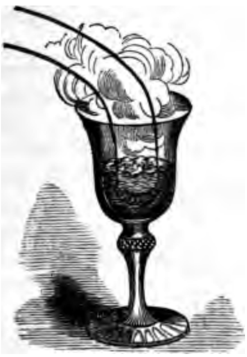


Fig. 13.

Experiment 20.—*To light a Candle by the Voltaic Battery.*—Use a similar arrangement to that described as used with the gas-jet (see Experiment 15), only let the fine wire twist twice round the black end of the wick, and touching it. On connecting the wire with the battery, the candle will be lit.

PRODUCTION OF LIGHT BY THE VOLTAIC BATTERY.

The most beautiful experiments in the whole course of experimental science are those we are now to describe. The battery we have advised you to construct will be quite sufficient to show all these effects, provided you take care that all your wires, &c., are bright and clean. Use sand-paper liberally for this purpose, for nothing is more necessary than complete connexions. Let not a spot of rust be on your apparatus. We have seen a battery at work at least 100 times the size of yours, and of the same construction, which produced at the lecture-table nothing like so good an effect as you may obtain, provided you pay implicit regard to our instructions.

To produce our results well and conveniently, the following simple apparatus may be made, although you can succeed without it by simply tying the different points we shall name to the end of the battery wires; still this arrangement will assist you materially, and ensure steadiness in supporting the articles you may experiment with.

On a piece of board, an inch thick, a foot long, and six inches wide, fix two upright wooden rods, say each a foot high. Attach a crayon-holder to each, either by screwing them on the rods, or by tying them on by a little wire; the arrangement will appear as represented in fig. 14. The wires of the battery must be attached to the end of each holder.

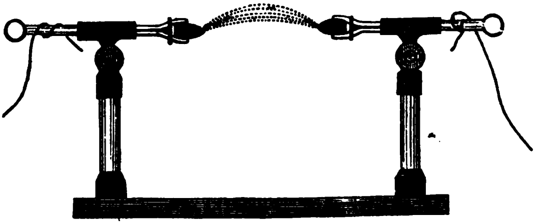


Fig. 14.

Experiment 21.—Having placed in the open ends of the crayon-holders two pieces of boxwood charcoal, or two pieces of the hard coke obtained from the top of the inside of gas retorts, bring the first two, pointed like a pencil, together until they touch. They will at once become red-hot; and if you then separate them to the extent of about an eighth of an inch, you will obtain a splendid light between the points; which, from the size of your battery, should light up a room twenty feet square very brilliantly.

This is called the electric light, and is the same that has been so often proposed for the purpose of lighting large towns by one light instead of by gas.

EXPERIMENT 22.—The objection to this light is twofold. In the first place, although so powerful, the light is very small, and, therefore, its shadows are very large. Place the hand before the light, and observe its shadow on the wall; it will be very dense. In the next place, you will find that the light will not last long, owing to the charcoal breaking away. Many attempts have been made to remedy this by the invention of what are called electric lamps, but with only partial success. Mons. Duboscq, of Paris, has made several of these. We have had three or four constructed for our own use, but in no case do we remember to have kept the light constant for more than twenty minutes, although we availed ourselves of every improvement that had been suggested, and used very powerful battery arrangements.

Our young friends may feel interested in learning the effect of different voltaic batteries, of a large size, in their power of affording light. We shall, therefore, give some results of some of our own experiments with batteries of every sort and size.

1st. Discarding all the old forms of battery, we fitted up, amongst many other arrangements, forty-eight cells of Grove's flat-cell battery, each cell containing sixteen square inches of active platina surface. This battery gave an arch of light between charcoal points of the length of nearly two inches and nearly three-eighths of an inch thick.

2nd. Seventy-two cells of Daniell's battery in *flat* cells. Each copper exposed a surface of two square feet, and was distant from the zinc about an inch on each side. From this we obtained a splendid light of about an inch and a quarter long and three quarters of an inch thick.

3rd. Twenty cells of Grove's battery, with platinas in a central porous pot, surrounded by zinc. The platinas were fourteen inches long and two inches wide. This gave a light of about three-eighths of an inch wide and half an inch long. This battery made a piece of platina-foil of the same thickness as that used in the cells, one inch wide and sixteen inches long, red-hot through its entire extent.

4th. Fifty cells of Bunsen's carbon battery. The carbons were one inch and a half wide and six inches long. This gave a flame half an inch long and an eighth of an inch wide.

5th. Fifty cells of Grove's round pots of the same size as the last, and arranged in a similar manner, but with platina instead of carbon, afforded, for nearly six hours, a light of one inch in length, and rather thicker than the last.

6th. One hundred cells of Grove's battery of the same as that we have recommended to our young friends as to size, with tobacco-pipe bowls, &c., gave a light an inch and a half long, and about as thick as an ordinary bell-wire. The shock from the battery was very severe.

Mr. Gassiot, of Clapham, obtained an arch of light three inches long, by using a battery of 100 cells of the same size as those mentioned in No. 1.

In all these experiments the effect on the eyes and face was very severe. The battery No. 2 produced a shadow at nine o'clock in the morning, when a piece of stick was held in the direct rays of the sun, shining clearly, and the experiment was tried about the early part of May, 1849.

Experiment 23.—The charcoal points do not give their light by combustion, as may be seen by placing the points under water, when you will obtain the light with ease. The light is produced by a portion of charcoal being transferred from one pole to the other. Indeed, the electric light is most effective when produced in the vacuum of an air-pump, where no ordinary combustion could possibly take place.

Experiment 24.—Remove the charcoal points from the crayon-holder (see Experiment 21), and place instead two pieces of copper wire. On bringing them in contact and separating them, a beautiful green light is produced.

Experiment 25.—Employ two pieces of silver, say two threepenny pieces; a green light of a brighter colour is produced.

Experiment 26.—In these two experiments, a most singular effect is produced on the face by the light; in fact, every object has a splendid green appearance, and with a powerful battery the effect on the spectators is very amusing. These are instances of a mono-chromatic or single-coloured light being produced.

Experiment 27.—Use two zinc points in the crayon-holders, and a fine blue light fringed with red will be afforded.

Experiment 28.—Into a wine-glass pour a little mercury, and place in it one of the wires from the battery. Introduce the other wire, and then withdraw it gently from the mercury surface. The mercury will burn with a bluish green flame. Take care not to inhale any of its fumes, which are given off in great *abundance.*

Experiment 29.—Hang a piece of watch-spring on the wire, and introduce it into the mercury, and withdraw it as in the last experiment. A splendid combustion of the steel spring will take place, and the sparks will be cast about in all directions, the spring being fused. Fig. 15 will give you an idea of the arrangement.

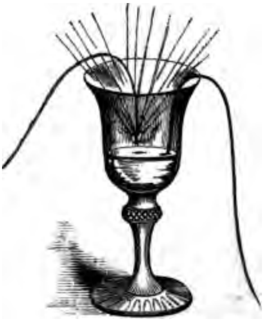


Fig. 15.

Experiment 30.—Put some iron filings into a tea-cup, and rest one of the wires from the battery in them; with the other stir the filings about continually. In a short time the whole will become red-hot, and sometimes the mass of filings becomes fused together. Occasionally, if the battery is in good action, the tea-cup will fly to pieces, owing to the heat produced.

Experiment 31.—Fill a glass with a strong solution of sulphate of copper, and introduce one wire from the battery. Dip the other wire into the liquid, and gradually withdraw it. A bright spark will be produced at the surface of the liquid.

Experiment 32.—Pour a little mercury into a wine-glass, and then fill the glass with cold water. Place one wire from the battery in the mercury, and then introduce the other so as to touch the mercury, and then draw it up. A combustion of the mercury will take place under the surface of the water, presenting a very singular appearance.

Experiment 33.—In the flame produced by the charcoal points (see Experiment 21), place a thin piece of zinc, platina, or other metal, and it will be immediately melted and undergo combustion.

Experiment 34.—Put a little mercury in a watch-glass, and on this sprinkle some iodine. Fix one of the wires in the mercury, and with the other cause the metal to burn. During the combustion the metal and the iodine will combine, and the yellow and red iodides of mercury will be produced.

ELECTRO-CHEMISTRY.

ELECTROTYPING.—PLATING AND GILDING.

THE Voltaic battery has been largely employed for the purpose of producing chemical changes on solutions of metals, &c., and this has given rise to an important branch of commerce.

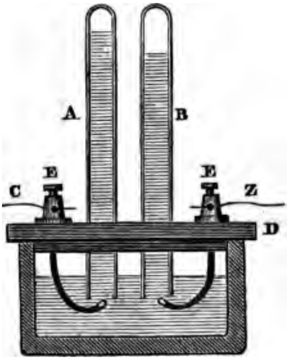
We have already stated that whilst using a Daniell's battery, the copper plate becomes coated with pure copper (see Experiment 7, p. 120). And if after a day's action you strip off this coat from the plate, which is easily done by filing the edge, and tearing the two metals asunder, you will observe that the new metal presents an exact copy of every mark and impression of the piece from which you have removed it.

To explain this result, we will try a few experiments; and as we must employ for this purpose the electricity of a voltaic battery, this branch of our subject has been called electro-chemistry.

EXPERIMENT 35.—Fix a piece of platina-foil to the end of each of the large battery wires, and dip the platinas into a wine-glass, containing a little sulphuric acid and water; you will find that the water is decomposed. Its two gases are given off separately, and if collected, they will be found to be oxygen and hydrogen in the proportions required to form water.

EXPERIMENT 36.—*To collect the Gases separately.*—Introduce the platinas into two test-tubes, which have been filled with acid and water, and place these, inverted, in a tumbler of acid water. Now cover the battery wires with a little sealing-wax, except at their points, so as to keep them from the action of the liquid. Press the unwaxed end of each wire on each platina. The water will be decomposed; and supposing that the tubes are of equal size, the hydrogen tube will, after a few minutes' action, contain a quantity of gas just double in bulk that of the oxygen one. When filled, apply a light to each, and the hydrogen in one will ignite, while the match introduced into the other tube will prove that it contains oxygen. Fig. 16 represents an

Fig. 16.



A and B represent the two tubes intended to receive the gases.

C and Z the wires coming from the copper or platina and zinc ends of the battery, and tipped with platina.

D, a cover in which the tubes rest.

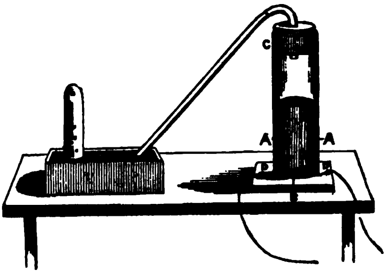
E E, two binding screws, through which the battery wires are passed.

arrangement very similar to the simple one we have described, and will enable our young friends to understand our instructions.

EXPERIMENT 37.—The two gases obtained from water may be collected together by a very simple piece of apparatus. Into a glass tube or a gas chimney fit two corks, so that when finally fixed they shall be water-tight. On each side of the inside of the glass put a small piece of platina-foil facing each other, and extending half an inch outside of the glass. These pieces will serve the double purpose of conductors inside and outside of the glass. Now press one of the corks into the glass, and so keep the foil in its place. The small pieces of platina on the outside may be bent outwards, and are intended to receive the conducting-wires of the battery. This will complete the bottom part of the arrangement. Into the top of the glass fit the other cork in which you have fixed a bent pewter or glass tube, and through which the gas produced will afterwards be carried away. The glass should previously be half-filled with some acid water, and may then be cemented by means of some sealing-wax to a piece of wood, which will serve as a stand. Fig. 17 represents the arrangement we have described.

On bringing the wires into contact with D D, the water inside the glass, will be decomposed; and if the bent tube is dipped beneath the water in a pneumatic trough, the two gases may be collected in any vessel, after the usual manner. When the tube is filled with gas, apply a light, and an explosion will at once take place, and water will be formed.

Fig. 17.



A A, two pieces of platina-foil, part of each extending outside the glass.

B, the bottom cork, to keep A A in their place.

C, a cork holding a tube through which the gases are to pass.

D D, the two outside pieces of platina-foil on which the wires of the battery are to be placed, and by which the electricity enters and leaves the water.

EXPERIMENT 38.—In a glass containing a little sulphate of copper dissolved in water, dip the two battery wires. Now very little (if any) gas will be given off; the hydrogen is employed in reducing the copper at the wire from the zinc end of the battery, and the wire from the platina end is gradually being eaten away by the oxygen set free at its surface.

EXPERIMENT 39.—Repeat the experiment; but use a piece of platina-foil instead of the copper wire from the zinc end of the battery. The platina will be coated with pure copper.

EXPERIMENT 40.—Remove the platina thus coated to the other wire, namely that from the platina end of the battery. It will now lose its copper; and if you employ another piece of platina-foil at the zinc end in the solution, the same copper you have thrown down on the foil in the last experiment will be transferred to the new piece of foil in this.

You thus observe that the hydrogen is invariably given off from that wire which comes from the zinc of the battery, and that the oxygen is always afforded at the wire coming from the platina end. These two ends or poles have had various names given to them. The end of the wire from the zinc has been called the negative pole, zincode or cathode; that from the platina end of the battery has been termed the positive pole, platinode or anode. The two wires are called electrodes, from the Greek word "odos," a way.

Now we have here the *pons asinorum* of electro-chemistry, for it is very difficult for the beginner to remember the relation of these poles to the parts of the battery. We shall, however, attempt to render this easy by using the following terms throughout our further remarks, viz.:—

We shall call the wire from the zinc end of the battery the "zinc wire," and that from the platina end the "platina wire," and shall use the same terms when speaking of the use of Daniell's battery (see Experiment 7), although it has no platina about it—because the copper is a substitute of the platina in Grove's battery. Remember that hydrogen is given off from the "zinc" wire, and oxygen, chlorine, &c., from the "platina" wire, when decomposition is going on.

Experiment 41.—*Decomposition of Salts.*—Divide a tumbler into two parts by means of a card, and pour in a solution of sulphate of soda, first coloured with a solution of litmus. Introduce the two platina poles attached to the wires of the battery, one on each side of the card. The salt will be decomposed: that side containing the "zinc wire" will keep of a blue colour, the other, or "platina wire" side, will turn to a bright red; the acid being set free here, and the alkali on the other side. (See fig. 18.)

Experiment 42.—Use a solution of common salt, coloured as in the last experiment. The chlorine set free at the "platina wire" will there bleach the litmus, and may be known by its smell. Fig. 18 represents the arrangement which you can employ for the purpose.

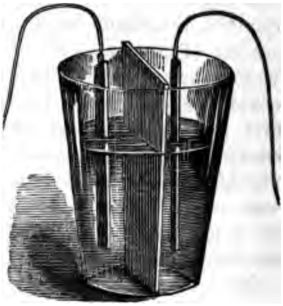


Fig. 18.

Experiment 43.—We shall now give you full directions as to the course to be adopted to ensure success in that interesting application of science called electrotyping. We have already, to some extent, anticipated the subject by our remarks on the construction of Daniell's battery in Experiment 7; but we shall now extend our experiments so as to instruct you how to apply electricity for the purpose of obtaining metal copies of any object you please.

The materials required are few. We premise that you have got a cell of Daniell's battery (see Experiment 7); besides this you will require some copper wire of No. 16 and 24 gauge, some white wax, a soft tooth-brush, some of the best black lead in powder, sulphate of copper in crystals, sulphuric acid, and a glass or stoneware pot, or what is perhaps better, a gutta-percha trough, twelve inches high and deep, and three inches wide. You can make a trough out of wood of the same size, and pitch it all over the inside, so as to render it water-tight.

EXPERIMENT 44.—For the purpose of making ourselves clearly understood, we shall suppose that you wish to have a copper copy of a plaster of Paris medallion, such as are sold by the Italian boys in the streets.

The medallion must first be placed in a plate containing a little water, and be left there until the water has soaked up to its surface. This is done so as to prevent the wax afterwards employed, from sticking to the surface.

When the plaster is well moistened, fasten round it a strip of paper slightly oiled, so as to form a ridge all round the medallion about an inch high. This will prevent the wax running away when poured on in its melted state.

Now melt some white wax, and pour it over the plaster cast until it forms a cake of about half an inch deep, and leave it till quite cold. When cold, you can easily separate the plaster from the wax, and you will then find that the latter affords a complete reverse copy of the cast.

White wax is a non-conductor of electricity; you must therefore make it a conductor by black-leading it. This is easily done by breathing on the wax, and then brushing its surface by means of a soft tooth-brush with black-lead until the whole is well polished. Only black-lead the side which you are about to cover with copper. Now heat a piece of copper-wire in a candle, and press it into the *back* of the wax until it is completely covered. This will form a kind of handle by which the wax mould can afterwards be hung in the trough. Black-lead the wax at the rim, so as to connect the black-leaded front and the wire, and thus complete the electrical connexion between the two.

The trough previously described must now be filled with a solution of sulphate of copper in water, to which acid has been added. This is prepared by dissolving in hot water as much sulphate of copper as it will take up, and adding thereto three ounces of sulphuric acid, diluted with a quarter of a pint of water for every pint of the copper solution employed. The trough being filled with this solution, a plate of old copper is now hung therein, and attached by means of a wire to the *copper* of the Daniell's battery, or to the *silver* plate of a Smee's arrangement. The black-leaded mould is now attached to the wire coming from the *zinc* of the battery, and placed facing, but not touching the copper plate in the solution in the trough. In the course of a few hours the copper will creep from the wire of the mould, and gradually cover the whole of the black-leaded surface, and in forty-eight hours the copper copy will be complete. The diagram (fig. 19) will give you an idea of the whole arrangement, where one of Smee's batteries is represented in action.

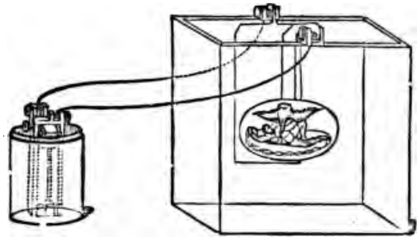


Fig. 19.

During the process you may at any time lift the mould from the trough, to examine the progress of the coating. Take care to maintain the action of the battery, if you use a Daniell's, by occasionally adding to its copper solution some sulphate of copper. The solution in the trough undergoes no change, and when once made, lasts any length of time if you just supply the loss of water caused by evaporation. If a Smee's battery is used, the whole requires no attention for a couple of days.

When the coating is complete, remove the electrotype from the trough, and separate the wax from the copper by introducing a penknife between the two. The superfluous rough edges may be cut off by a pair of scissors, and the face of the metal brushed clean. It is easy to mount these on a card by just cutting out a hole sufficiently large to receive the electrotypes; or they may be silvered or gilt by the process we shall shortly describe.

The plan we have described can be applied in any way you may wish, to obtain electrotypes from solid objects. To make them from fruit, lace collars, &c., requires more care, and we shall now give directions in respect thereto.

Experiment 45.—*To obtain Electrotypes of Lace Collars, &c.*—A very pretty amusement for young ladies is that of copying, or rather coating in copper such articles as lace collars, and leaves of trees out of which the solid matter has been taken. To coat a lace collar, you must dip it in very hot melted wax, and afterwards let all the loose wax run off. Hang it by a pin until quite cold. It must now be black-leaded as before described, and hung in the trough for about twelve hours, until completely coated. It may then either be silvered or gilt, and we have seen some beautiful specimens of bracelets and collars thus produced, and the more valued as they were recognised as the production of their owners' ingenuity.

Experiment 46.—Fruit may be electrotyped in a similar manner; as, for instance, an apple. It should be dipped in melted wax, and be hung in the trough after being black-leaded by means of a pin driven into it, to which the wire from the zinc of the battery is attached. So exact is this process, that you can even electrotype the very finger-marks; and should you carelessly mark the face of your wax mould thus, you will see an exact impression on the electrotype. Many persons have applied electrotyping to the purpose of copying engraved plates, but owing to the metal produced being soft, plates so made do not last so long as those produced by rolling.

Experiment 47.—By reversing the position of a plate coated with wax, and having portions of the wax removed, electro-etching may be carried on. For this purpose cover a copper plate with white wax, and when quite cold remove, by means of a needle, that part of the wax where you desire to remove the copper. The wax must be taken away so as to expose the copper surface. The plate is now to be hung in the trough, and attached to the *copper* of the battery, and a piece of copper plate attached to the *zinc* of the battery hung in front of it. After a few hours the copper plate will be completely "eat in," and by cleaning off the wax, and filling the etched part with printers' ink, you may print from it with ease, taking care to clean all the ink off the plate, except that left in the hollow lines.

Experiment 48.—In our remarks hitherto, we have endeavoured to put you in possession of the best mode of obtaining electrotypes, and have not mentioned the single-cell plan. Although it is the simplest, it is not the most certain mode of proceeding; and we only add a description of it, to make our subject more complete, while we prefer the mode already described. Presuming that you are desirous of depositing copper on a wax mould already black-leaded, &c., as before described, you must attach the wire from the mould to a strip of zinc placed in a porous pot, and charged with a solution of common salt or sal-ammoniac in water. Next to the mould, in an outer earthen or glass pot, pour the solution described in *Experiment* 44, and keep up its strength by continually adding crystals of sulphate of copper. The mould in this arrangement forms the negative plate of a battery, and it will be gradually covered with copper in the same way as the copper plate of a Daniell's battery. Fig. 20 illustrates this arrangement.

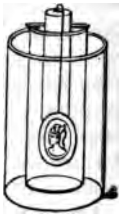


Fig. 20.

The chief objection to this plan is the irregularity in the quality of the metal thrown down. Sometimes it is hard, crystalline, and brittle, and generally you will find our previously-described method the most eligible.

ELECTRO-PLATING AND GILDING.

Electro-plating and gilding are carried on precisely in the same way as that for depositing copper, the only change being in the solution, and in the metals employed as positive or soluble poles.

The article which you are about to plate must be carefully cleansed by dipping it into a little weak nitric acid, until every trace of oxide disappears. It is then to be attached to the wire proceeding from the zinc end of the battery cell, and immersed in the silver or gold solution. A piece of silver or gold, according as you are plating or gilding, must be attached to the wire from the copper end of the battery, and dipped in the liquid. The solutions should be used in glass jars, and not in the trough, as they are more valuable, and should be kept carefully free from any admixture.

You must also procure the metals in a pure state, as silver or gold coin contain copper, and would spoil the solutions. Obtain a piece of pure silver foil of about two inches in length and an inch wide, and a piece of gold of the same size. The thickness is of no consequence, and the cost of the silver should be about one shilling ; the gold, of course, is more expensive.

Experiment 49. — *Electro-plating Solution.* — Dissolve half an ounce of nitrate of silver in distilled water (cold boiled water will not do). Add to this solution, clear lime-water, as long as a brown powder falls down. Collect this powder by means of a filter of blotting-paper, and in a pint of water dissolve an ounce of cyanide of potassium. When this is completely dissolved, put into it the filtering paper containing the brown powder of the oxide of silver, and stir it till all is dissolved. Pour off the clear solution, and you thus obtain the electroplating liquid. If not quite clear, you can filter it through a sheet of blotting-paper.

EXPERIMENT 50.—*To Silver a Mould or other Object.*—Pour the above-named solution into a glass jar, and introduce into it the mould, which must be quite clean and attached to the zinc wire of the battery. Opposite to it place the silver-foil, attached to the other wire of the battery. In three or four minutes the whole surface of the mould will be coated with pure silver. It is now to be removed from the glass jar, well washed in water, and may be polished by adopting the usual mode of polishing silver articles employed in domestic use.

Of course the thickness of the coating will depend on the length of time you expose the mould to the action of the battery. We name three or four minutes as giving time for a sufficient average thickness.

By adopting this plan, you may plate any metal article. In every case be careful to cleanse whatever you plate most perfectly, and always introduce the article and the silver pole at the same time into the solution, as you thereby prevent the chance of the former being acted on by the plating liquid.

EXPERIMENT 51.—Electro-gilding is carried on in precisely the same manner; the solution of oxide of gold in cyanide of potassium being used, and a gold instead of a silver pole being employed. We need not give further directions as to the preparation of the solution, as it is precisely similar to that recommended in our instructions as to the silver liquid. Our young friends had better buy this solution ready made; and even if they reside any distance from a large town where all the requisites of electro-plating and gilding are sold, still by going to any respectable chemist he will easily obtain everything we have described.

As soon as you have completed your experiments with either the silver or gold solutions, restore them to their proper bottles; and should they, in course of time, get dirty, filter them through blotting-paper.

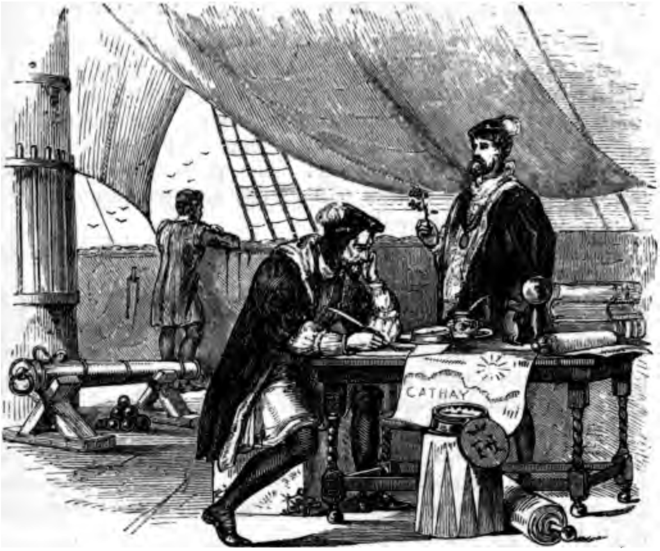
Remember in adopting the *battery* process your *solutions* are never affected. The metal thrown down on the objects you plate is obtained from the positive pole, and is transferred *through* the liquid on to the article plated. In fact, to use a common phrase, it is a case of "Robbing Peter to pay Paul." In the *single* cell process, described in Experiment 48, such is not the case. The *solution* loses exactly as much as the article in process of coating receives, and without great care the zinc in the porous pot may pass through; and if the liquid you employ is either the plating or gilding one, it would be certainly spoiled.

EXPERIMENT 52.—As a kind of appendix to our electro-chemical experiments, we shall give some directions for repeating Sir Humphrey Davy's results obtained by the decomposition of the alkalies. Place a piece of fused potass on a piece of platina-foil; breathe gently, so as to slightly moisten it. Attach one wire from the battery of twenty cells to the platina plate, and touch the potass with a piece of platina attached to the other wire of the battery. The potass will be speedily decomposed, bright sparks will fly off, and potassium in very minute quantities be produced.

EXPERIMENT 53.—Repeat the experiments with soda, and sodium will be produced.

EXPERIMENT 54.—Try the experiments again by placing the potass or soda on a little mercury. This metal will form an amalgam with either potassium or sodium; and if you throw the amalgam thus formed into cold water, the water will be decomposed, and pure hydrogen given off in very small bubbles.

These experiments open out a most interesting field of inquiry, and science is indebted chiefly to Dr. Faraday and M. Becquerel for their extensive researches in electro-chemistry, and also for the many useful applications which have been made of its laws.



EXPERIMENTS IN MAGNETISM.

We may safely presume that all our young readers know what a magnet is, and, perhaps, as surely predict that very few know what makes a piece of steel magnetic. It will therefore be our duty to supply this information as far as we can, and by a variety of experiments we hope to render our remarks both useful and interesting.

The term Magnet has been derived from the name of the country, Magnesia, in which the "loadstone" abounds, and seems to have been first discovered. Our young friends should procure a piece of this magnetic earth. Why steel should be almost the only metal which can "store" the magnetic force is an inquiry we cannot explain. Professor Faraday, to whom we are indebted for some most valuable discoveries in this science, has succeeded in showing that everything is susceptible of magnetic influence, and has thus laid the foundation of a science called Dia-magnetism. In fact, he has proved that a ray of light, and even a leg of mutton, may be influenced by a powerful magnet; but as the repetition of these experiments, so interest*ing to the philosopher*, is impossible to any of our young friends unless they possess expensive and peculiar apparatus, we shall content ourselves by naming the facts, and shall at once proceed to suggest experiments which will be easy and amusing.

EXPERIMENT 1.—Rub a common sewing-needle with a piece of "loadstone." Present to it another needle, and you will find that it is drawn or *attracted* by the needle you rubbed. This effect is called *magnetic attraction.*

EXPERIMENT 2.—Rub two sewing-needles, either by the loadstone or by a common horse-shoe magnet. Now place one of these needles on the surface of a basin of water, on which it will easily swim. Present either end of the other needle to this, and you will find that one end attracts or draws to, and the other repels or drives away. This last effect is called *magnetic repulsion.*

EXPERIMENT 3.—The success of our last experiment is owing to the needle becoming what is called polarized; or, in other words, you have communicated to it the power of pointing nearly north and south. Now each of these needles has two poles, and if you present a north pole to a north pole, the needles repel or drive each other away; but if you present a north to a south pole they attract each other. We here see an illustration of a law of this science which is, "that two similar poles repel, and two dissimilar poles attract each other."

EXPERIMENT 4.—*The Mariner's Compass.*—This is simply a needle of steel which has been well magnetized by rubbing it with a powerful magnet, attached to a piece of cardboard, on which the "points of the compass," as they are called, are marked. This is suspended on a fine pivot, and allowed to move freely thereon. You can easily obtain the same result by placing a magnetized sewing-needle on water. If on a clear night you place the basin with the swimming-needle in the open air, and look for the pole star in the heavens, you will find that your needle points a little to the left of it—that is, north-west. You may turn the needle as often as you please, but still it will come back to its old position. Now, to this strange effect our sailors are indebted for an instrument by which, in fine or cloudy weather, they can always tell the north part of the heavens, and have not, like Ulysses and the other old navigators, to wait until a clear day or night sets them right in their course, by allowing them to see the sun or the stars.

We have said that the needle does not point true north. This is owing to what is called the variation of the needle, and the reason of it is, that the earth itself is a huge magnet whose poles act on those of the needle. Hence the poles of magnets vary in different countries from true north. In a place west of

Greenland the magnetic pole is found, namely, in lat. 70° 5′, and long. 96° 45′.

We may here tell you that those strange people, the Chinese, use the needle as we do, and have known its value for centuries, but call the north pole south; in fact, their customs and habits are most frequently the reverse of those of every civilized race.

EXPERIMENT 5.—Many vessels have been shipwrecked owing to the action on the compasses, of iron which formed either the cargo or material of the vessel. Thus, some years ago, the Great Britain went ashore at Dundrum Bay, in Ireland, from a derangement of her compasses. You may easily see the reason of this by holding a piece of soft iron outside of the basin in which your needle is swimming. The iron will attract the needle, and continue to do so as long as they are near together.

You will often read in the papers of a vessel "having her compasses adjusted." This is done for the purpose of correcting the errors which we have just named. The vessel is taken to some place where there is sufficient water to allow her to swing right round the chain of her anchor, as the tide goes out and comes in. The compass is carefully watched, and if, during the swinging of the vessel, the needle varies from pointing always to the same object viewed at a distance off, this is corrected by placing magnets or pieces of iron in such a position as will destroy all the effect of the vessel's cargo, &c., on the needle. Of course these magnets are never touched again during the voyage.

To give you some idea of the necessity of this, we will relate an incident which happened once to us in crossing from Ayr to Campbeltown, at the mouth of the Clyde. We started from Ayr by a steamer in a dense fog, intending to call at the south end of the Isle of Arran. We could not see the length of the vessel ahead, and steamed on cautiously until we thought that we should have arrived at our first port. To our great surprise we found ourselves at the north end, some eight miles from our destination; and in fact, although we had steered, as we thought, direct *west*, we had, owing to our compasses being out of order, actually gone nearly due north the whole time. Of course, had this happened at night, it is more than probable that we should have all been lost; indeed, nothing could have saved us from being dashed to pieces on the iron-bound coast at the foot of Goatfell, a large mountain on the island.

Speaking of the supposed effects of fog on the compasses, some persons affirm that fog renders the needle inactive. We have conversed with many intelligent captains of vessels, and the majority do not believe in such an effect. Errors are often produced by carelessness; and one captain related that during a voyage he had been going the wrong course for some hours, owing to a stupid cabin-boy having placed a box of knives he had been cleaning near the compass-box.

Experiment 6.—*The Dipping Needle.*—A piece of magnetized steel not only points north and south, but will also, if freely suspended at its centre, dip or hang towards the earth. This experiment is easily tried by magnetizing a scale-beam. Of course it will, before being magnetized, be in an horizontal position, but on rubbing each end with the different poles of a strong horse-shoe magnet, one end will dip or hang toward the earth at an angle of 67°.

Experiment 7.—Another way of producing a dipping-needle is to first balance a piece of steel on a pivot, supported by two stands; then magnetize it, and again suspend it on its supports, and you will find its balance lost, and the dip at once produced as in fig. 1.

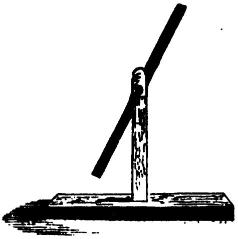


Fig. 1.

Experiment 8.—*To make Magnets.*—We have already shown how easily needles, &c., may be magnetized (see Experiment 1). Should you wish a large straight magnet, procure a piece of good steel, and having polished it with emery, rub each end repeatedly with a strong horse-shoe magnet, commencing from the centre outward toward each end. Take care each time to rub the end of the steel with the same end of the magnet as that you commenced with, otherwise your labour will be lost. To assist you in this, you will find that the horse-shoe magnets have one end always marked. This is their *north* pole. Having rubbed one end of the steel with this, rub the other end in the same manner with the south pole, until you have communicated sufficient magnetism.

Horse-shoe magnets may be purchased at any ironmongers for from threepence to five shillings each. When a powerful permanent magnet is required, a number of these are bound together, and so form what is called a compound magnet. One of steel, with its keeper, or soft piece of iron, is represented in fig. 2.

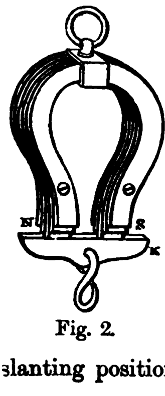


Fig. 2.

Experiment 9.—Place a steel poker in a slanting position, and pointing nearly north and south. Now strike it repeatedly with a piece of iron. It will soon become magnetized.

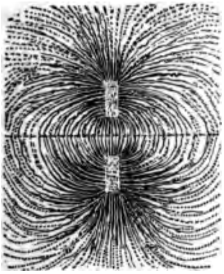


Fig. 3.

EXPERIMENT 10.—Send a powerful charge of a Leyden battery along a sewing-needle. It will sometimes become magnetic.

EXPERIMENT 11.—Sprinkle some iron filings on a sheet of paper, and bring near them a horse-shoe magnet, or place this under the paper. Beautiful curves will be formed, as in fig. 3, where the two ends of a horse-shoe magnet are represented, surrounded with iron filings.

EXPERIMENT 12.—Large magnets are capable of supporting heavy weights. Present the horse-shoe magnet to the centre of a poker or other iron substance. If the magnet be of moderate power, it will sustain it with ease.

EXPERIMENT 13.—Amusing toys may be made by you. For instance, place a small piece of magnetized steel in the beak of a wooden swan. If you now float the bird in a basin of water, and present a piece of bread enclosing a horse-shoe magnet, the bird can be easily drawn towards the bread. Now turn the bread, and present the other pole to its beak; the bird will swim away from the bread.

Magnetic fishes, and a variety of other such matters, may be made if our young friends ingeniously adopt the principles we have already explained.

A very amusing illustration of magnetism was exhibited at the Adelaide Gallery, many years ago. A negro head was fastened to the body by means of two magnets, and the lecturer used to try to cut the head from the shoulders by means of a knife, in which of course he could not succeed, although the knife passed through.

TELEGRAPH - OFFICE.

ELECTRO-MAGNETISM.

ELEMENTARY EXPERIMENTS.

Having considered some facts referring to magnetism, we now proceed to show how the science of Electricity is connected with it; indeed, the most effectual mode of producing magnets is by means of electricity obtained from the Voltaic battery. We must here remind you that although many eminent continental scientific men are ranked amongst the discoverers and inventors in this branch of science, termed electro-magnetism, still we are more indebted to Professor Faraday, of the Royal Institution, London, than to any other, for the extent of our knowledge of the subject.

Experiment 14.—In our magnetic experiments we have almost always spoken of *steel* in connexion with magnetism, and we should here state, that although iron may have this force induced or produced in it, still soft iron has not the power of retaining it. Thus, if you present a piece of soft iron to the end or pole of a magnet, the soft iron will hold nails or filings so long as the magnet is in connexion with it, but no longer; whereas steel retains the force, and becomes what we term a permanent magnet.

EXPERIMENT 15.—We are enabled, however, by means of the Voltaic current, to produce a temporary magnet of enormous power with soft iron. To produce one of these, wind round a piece of gutta-percha tubing, an inch in diameter and eight inches long, a length of fifty feet of copper wire, No. 16 gauge, which has been covered with cotton. This may be procured from any philosophical instrument-maker for about 2s. 6d. per pound, and half a pound will be sufficient for your purpose. Wind the wire round the gutta-percha tube exactly as cotton is wound round a cotton-reel, and in an even manner, leaving out the two ends extending to a foot in length each. One of these coils is represented in fig. 4. Now place a piece of iron rod in the centre, and stretching lengthways through the tube, so that its ends extend two inches at either end of the tube. Apply an iron nail, and you will find no effect of any sort produced.

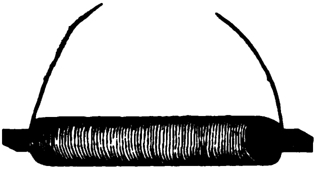


Fig. 4.

EXPERIMENT 16.—Repeat this, but apply the wires of your battery of twenty cells, one to each wire of the coil. If you now throw a pound of iron nails at the end of your iron rod, and lift the coil from the table with the battery wires still attached, you will find that every nail adheres, and you will thus obtain an astonishing amount of magnetism by sending an electric current *round* a rod of soft iron.

EXPERIMENT 17.—Remove either, or both, of the battery-wires. The nails will immediately fall down, showing that the magnetism ceases on the passage of the voltaic current being stopped.

EXPERIMENT 18.—Repeat the experiment with a *steel*, instead of an iron, rod, and the steel will become a permanent magnet.

EXPERIMENT 19.—Instead of sending the electricity *round* the iron, send it *through* it, by connecting the battery-wires *with its two ends*. You will now find no effect produced.

From these experiments you will thus learn that you must send your current of electricity in a particular way to produce the magnetic effect. Now this way, rule, or law, is thus expressed:—"When a current of electricity passes by means of a conductor, magnetic effects are induced at right angles to its road or passage." Thus, in Experiment 15 your current passes *across* the coil, and your magnetic effect was produced at *each end* of it, or lengthwise.

You must carefully bear this in mind, as this is what we shall call the "Rubicon" of electro-magnetism, which, if you once get over, every experiment will become easily understood by you.

Experiment 20.—Our rule is so true, that even a copper wire may be made magnetic under certain circumstances. To show this, have soldered to the end of a piece of covered copper wire, two feet long, a piece each of zinc and copper. These may be two inches long and one wide. Now twist your wire round a piece of card, so as to form it into a kind of screw, or, as it is generally called, a helix, letting the plates of zinc and copper hang down facing each other. Hang this by a piece of silk thread fixed in the centre of the coil, and hold the other end of the thread in the fingers, letting the copper and zinc plate dip into a glass holding sulphuric acid and water, as in fig. 5. If you now, with the other hand, present a magnet to the copper coil, you will find it either repels or attracts the coil, which has by the electric current become polar and magnetic.

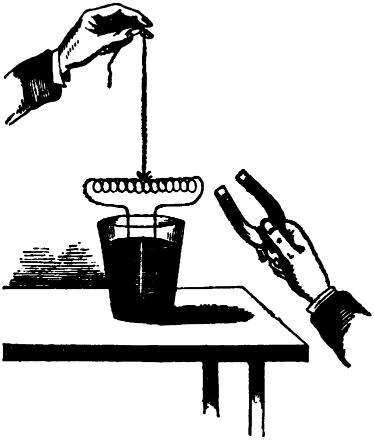


Fig. 5.

EXPERIMENT 21.—Repeat this experiment, and prove the polarity of the suspended coil, by bringing alternately the two poles of the magnet to the two sides of the coil, and thus you will find that the wire has become completely magnetic.

EXPERIMENT 22.—Lift the wire and plates from the liquid, and again present the magnet, and you will find that all effect has ceased, owing to no current of electricity passing over it.

EXPERIMENT 23.—Bring the needle of a mariner's compass to the extreme ends of the coil. The needle will be repelled or attracted according to the poles you present to it.

EXPERIMENT 24.—On these principles electro-magnets are constructed, and some have been made which would hold enormous weights. The one lately possessed by the Glasgow Polytechnic would sustain a weight of some tons; and we have frequently in our lectures had thrown on the two poles one hundredweight each of iron nails, each nail measuring four inches long. The nails adhered so firmly that it required great force to separate one from the mass.

An electro-magnet of a small size, which will sustain from fifty to one hundred pounds, may be made at little cost. Get the blacksmith to bend for you a piece of rod iron, twelve inches long and an inch thick, into the shape shown in fig. 6, and let the ends be carefully filed until they are quite flat. *Now wind round* this, in the same way as you did on the gutta-

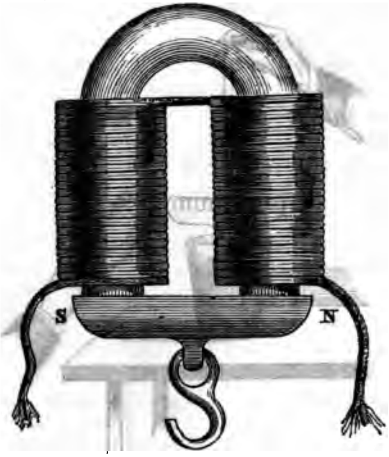


Fig. 6.

percha tube (see Experiment 15), half a pound of covered copper wire, No. 16 gauge; only do not wind it all the way round; but having wound one half down, commencing from the top of one leg, take the wire on to the other side, and wind it thereon, leaving the two ends out, as represented in fig. 6.

EXPERIMENT 25.—If you now connect these end wires with the twenty-cell battery, and present a piece of flat iron to S and N, fig. 6, it will be attracted with enormous force; and if your battery is in good action, it will require you to hang a weight of nearly one hundred pounds before the iron will separate from the magnet.

EXPERIMENT 26.—Disconnect the battery wires, and you will find all the magnetism lost. The large magnet to which we before referred, was so free from magnetism before the current passed over it as not to hold the finest sewing-needle, although sustaining such enormous weights when electrified. Should, however, the iron of your electro-magnet be not very soft, it will retain a little of the force for some time. This has been called "residual magnetism."

One would naturally suppose that a force of such an extent, and so easily excited, would have been long ere this applied to purposes such as the steam-engine is used for. Owing, however, to the expense of working electro-magnetic engines, and to the fact that, although the force at the face of the magnet is so great, yet it diminishes so rapidly, that we regret to say no success has yet been made in any attempt to apply it.

EXPERIMENT 27.—The last reason of failure is easily perceived by presenting a nail at two inches from the pole of the electro-magnet. You will find it scarcely drawn towards the pole, although it adheres strongly when resting on the surface.

Caution.—When placing the iron on the face of the magnet, take care not to place the fingers between the two, as in that case they will be sharply pinched. When lecturing once with the large magnet in action, we overheard two of our audience boldly declare that the nails were glued to the poles. After concluding, we invited one of these gentlemen to place his finger between the magnet and the iron plate. The squeeze he got fully persuaded him of his error, and by a tremendous scream he announced the fact to the rest of the audience.

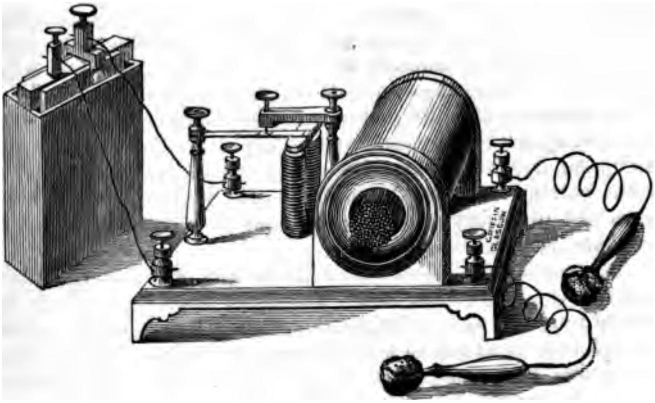


Fig. 7.

THE COIL MACHINE.

We shall now describe a machine by which you may *feel* instead of *see* the effects of electricity.

The coil machine has been long used for medical purposes, and has been made of every variety of shape; but we shall endeavour to suggest to you one of a simple kind, which will answer every purpose, and that will cost you very little.

Experiment 28.—Get a reel of wood made at a turner's, eight inches long, and with a hole through its whole length, of about an inch in diameter. It must have a collar at each end four inches deep. Its shape is represented in fig. 7.

On this wind, as we explained in Experiment 15, half a pound of covered copper wire, of No. 16 gauge, bringing out each end through the collars. This forms what is called the primary coil. On this primary coil you must carefully wind a second one; this should consist of a pound and a half of No. 24 covered copper wire. The ends of this coil must also be brought out of the collars. The coil thus formed will consist of two separate coils, the fine one wound round the coarse one, and their two ends extending a foot each from the reel, but not being brought in contact. Into the centre hole of the reel put a bundle of iron wires through its whole length. You must now solder to two pieces of tin or brass pipe, an inch wide and four inches long, two wires, and attach these to the end of the fine coil wires. One of the wires of the inner thick coil may be attached to the copper of a cell of Daniell's battery (see Voltaic Electricity), and the other end of the coil may be twisted round the end of a file. If you now rub the wire, from the zinc end of the battery, over the edges of the file, and invite a friend to take hold of the two handles of the fine coil, he will experience a most powerful shock; and if you keep on rubbing away briskly at the file, he will not be able to leave hold of the handles, owing to the powerful contraction of the muscles of his arms.

For the purpose of making the coil self-acting, you must have what is called a contact-breaker; and we must here state that the shock is obtained by what is called induction. In other words, when you send through or stop a current in the primary or thick coil, you generate one in the fine coil, although they have no connexion with each other. It is just as if you were to strike another person, and that he should fall against one standing near him. Now you would, in that case, hit only the one nearest you, and yet the third person suffers; in the same way, the voltaic current of the battery affects the fine coil, and sets free its electricity, although it is separated entirely from it, and merely passes through the primary one.

As a contact-breaker is not easily made, we would just suggest, as a substitute, that you may attach one end of the battery to the coil, as before explained; but instead of attaching the other coil wire to a file, dip it into a cup holding mercury, and by dipping and removing the other battery wire into this cup, contact may easily be made and broken.

Our illustration at the head of the section will give you an idea of the usual construction of a complete coil-machine. One of this kind may be purchased for from twelve shillings to two pounds, and with proper care they will last for years.

We must warn you of a result which often takes place. The muscular contractions are so powerful, that the person taking the shock is not able to control his feelings; and we have before now seen battery, coil, and the person shocked, all lain on the floor together. Our young friends may be amused at the following incident. Whilst lecturing at an institution near London, the audience were much annoyed at the intrusion of a person who had been drinking freely. After the lecture this individual determined to take a shock. We put on a powerful battery, which caused him to jump over a form four feet high. We considered that we were fully entitled to the thanks of the directors, as by this incident this worthy individual was induced to be very cautious how he ever afterwards made his appearance in public.

The strength of the shock may be much lessened by removing the bundle of iron wires from the centre of the coil. If a very slight shock is to be given, the wires may be divided by a little water. If you wish to give a "good shock," let the person receiving it moisten his hands with a little salt and water; and lastly the shock may be taken by putting the two wires of the secondary coil in two basins of salt and water, and any person taking a shock must place his fingers in each.

EXPERIMENT 29.—Four or more persons may receive a shock by first wetting their hands and joining together; but the effect, although more continuous, is not so severe amongst a number of persons as that obtained from a Leyden jar.

Rhumkorff's Coil.—This coil is constructed simply on an extension of the principles on which the coil we have just described is made, with the addition of what is termed a condenser. The secondary coil is something like two or three miles long, and by means of it all the experiments, both of frictional and voltaic electricity, may be performed. As the apparatus is very expensive, we shall not further allude to it. It is, in fact, a dangerous instrument in the hands of an inexperienced experimenter, although in a philosophical point of view it is one of the most interesting arrangements which have been produced in connexion with physical science. The writer twice received powerful shocks from one; and it is no exaggeration to say that no person, under any inducement, would attempt a repetition of such an occurrence.

THE ELECTRIC TELEGRAPH.

We shall now endeavour not only to explain the principles on which the electric telegraph is constructed and worked, but also give you full directions which will enable you to make a simple one for your own use, the study of which will make it easy for you to understand how it is that we are able to send instantaneous messages, conveying our wishes to any part of the world.

Some people have most strange ideas as to the means employed. As an instance of this, we may mention that on one occasion a friend of ours, a well-known public character, was desirous of telegraphing from Glasgow to London; and thinking that we knew more about the matter than he really did, at his request we proceeded to the telegraph station at the *Exchange*. After writing the message, he read it over, and requested us to rewrite it, as he was afraid we had not written it plain enough, and stating at the same time, that the clerks in London would not otherwise be able to read it. On asking him what he meant, he at once said that, of course, the paper on which we had written would be sent to London.

Now, we need not tell you that it would be impossible to send a piece of paper by means of the telegraph wires,—but we can send something else, and that is a current of electricity. But how does this current take our message? This inquiry we will at once answer.

EXPERIMENT 30.—Place a magnetized sewing-needle (see Experiment 1) on the surface of some water in a basin, and when the needle is at rest, place over it, but not touching it, and in the same straight line, a copper wire. This is easily done by nearly filling the basin with water, and stretching over the needle the copper wire, as shown in fig. 8. Of course the copper wire will have, of itself, no effect on the needle. Now bring the wire from the zinc end of the battery to touch the copper wire at one end, and the wire from the platina end to touch at the other; the moment the battery wires touch the copper wire the needle will turn from its position, and the north pole will be turned towards either the right or left hand. Now change the position of the battery wires, first restoring the needle to its old position, and making the current pass in the reverse direction; the needle will turn in the other direction at the same time. This action our annexed illustration will explain more fully.

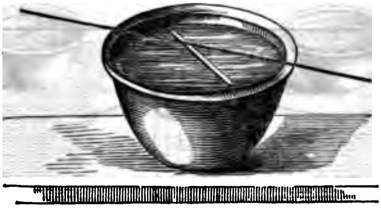


Fig. 8.

In fig. 9, No. 1, the current of the battery is passing from P to Z, and the north end of the needle is directed to the right.

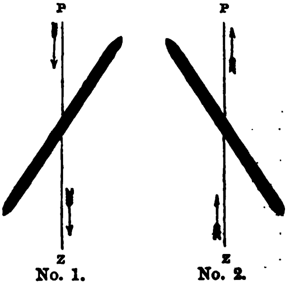


Fig. 9.

In No. 2, the current is passing from Z to P, and the top of the needle turns to the left hand, the direction of the current being the reverse of that in No. 1, as indicated by the arrows.

Now, all the difficulty of understanding the electric telegraph will be at once solved by your trying this simple experiment. You will thereby see that a wire carrying the electric force has the power of turning the needle right or left, according to the direction the current takes, and it is simply by this diverging of the needle repeatedly, by the current passing along the wires, that the messages conveyed from one station to another are indicated on the face of the instrument.

Experiment 31.—To understand this better, use two basins and two needles swimming on water, with one wire passing over the needle of each basin, as represented in fig. 10. Let each basin be placed at the end of a table, and let the wire be continued over each, with its two ends free. The basins will represent two distant stations, and we will suppose a battery to be at one of them. Now place the zinc wire of the battery in connection with the wire from the left-hand basin, and the other battery wire attached to that from the right-hand one. The moment the battery wires send their current through the copper wire, the north poles of the needles in the basin will be diverged each in the same direction, towards the right-hand side. Remove the battery wires, and let the needles come to rest again. Now reverse the battery wires, and you will see that the north poles of the needles will now turn to the left-hand side.

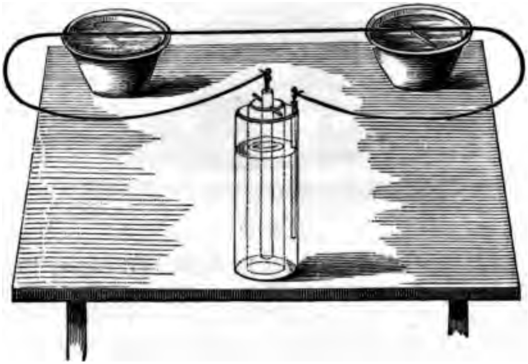


Fig. 10.

From this you will learn that by means of a conducting-wire stretched over two needles at any distance from each other, you can, by the voltaic current sent through the conductor, deflect both needles at the same moment.

You may extend this experiment by placing one basin in the kitchen and the other in the parlour. Your conducting-wire may be twisted or nailed in its course, each end being brought to the battery. By having a friend down-stairs, on your sending the current by the wire, you may send an elementary message by yours, at the same time agreeing as to the signal. For instance, we will say one turn of the needle to the left shall represent the word "come up," and one to the right the word "stay down." By repeating this a few times you will plainly see all the art and mystery of the electric telegraph in practical operation.

In practice, the arrangement of course is very different, as far as regards the mechanical detail. Only one conducting-wire is used, the earth being made to serve as the other one, by each station having a large plate buried in the ground, and attached by a wire to the instrument; the moisture of the earth between any two places thus serves the purpose of a wire. The needles are hung on a pivot vertically, and round them is wound several feet of fine covered copper wire, instead of the one wire we have used. Batteries of several cells are employed to send the current any distance; and according as the distance increases between the stations, so the number of cells employed must be increased.

In front of the needles a card is fixed, on which are printed the various letters of the alphabet; and by means of what are called reversing handles, the needles are rapidly turned right or left, and the letters of any word are thus spelt.

For instance, supposing we wish to send the following message to a friend, "Come at once;" we shall have to deflect the needle right or left as many times for each letter as are indicated by an arranged code of signals. This is done by simply moving handles placed in front of the instrument, which have arranged at their further end two wires dipping into mercury cups, and respectively connected with the battery and the wires through which the current passes.

In fig. 11 we have an illustration of one of the instruments generally employed in the ordinary telegraphic arrangements, where needles, handles, &c., are represented. By using two needles, and combining their deflections, much time is saved in spelling the message. A bell connected with the wires was at one time employed for the purpose of calling the attention of the clerks, but it is now rarely used. The current was partly diverged from the needles by a peculiar arrangement, and acting on a stop in some clock-work set the bell in action.

There is a great variety of printing telegraphs employed, both here and in America. In the latter country Morse's telegraph is much employed; in our own, Cooke and Wheatstone's, which we have just described, is mostly used. Messrs. Bain, Henley, and Bakewell have invented ingenious arrangements, but we shall not detain you by describing them. We shall give, however, an experiment further on, illustrating the principles on which they work. In submarine telegraphs the wires are coated with gutta-percha, to prevent the electricity escaping through the conducting power of the water. The gutta-percha covering is surrounded by thick iron wires, so as to resist the action of stones, &c., in the bed of the ocean.

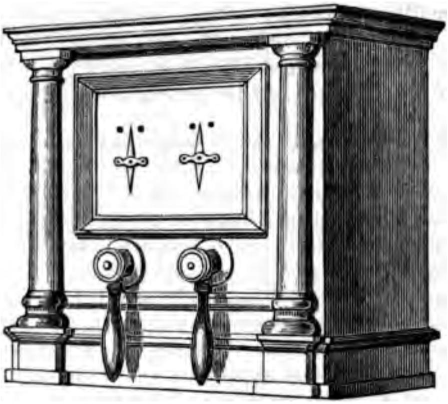


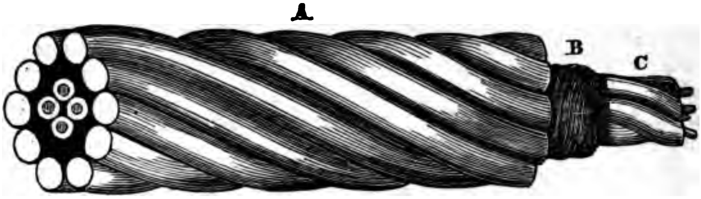
Fig. 11.

Our illustration (fig. 12) will give you an idea of the construction of a submarine cable.

The Atlantic cable only contained one conducting-wire. The wires of the Electric Telegraph Company are mostly suspended in the air on posts, whilst the Magnetic Company enclose theirs in gutta-percha, and bury the wires in the ground in iron tubes.

Experiment 32.—Our young friends will easily understand the action of the printing telegraphs by the following experiment:—Wet a piece of white calico in a weak solution of prussiate of potass, afterwards dipping it in a solution of sulphate of soda. Press the cotton until all superfluous moisture is driven out. Now lay it on a sheet of tinfoil. Attach a knitting-needle to one wire from the battery, and rest the other wire on the tinfoil on which the calico is placed. If you then draw the knitting-needle over the cloth, a blue mark is left. If you just press it down, there will be simply a spot. By an arrangement of this sort printing telegraphs are worked.

Fig. 12.



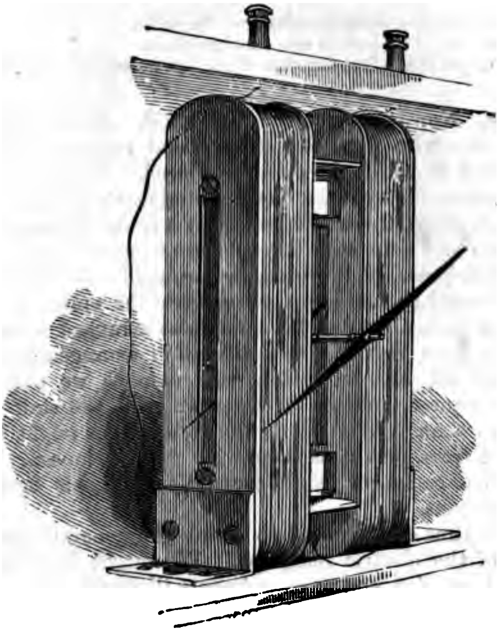
A, the iron wires surrounding the cable.
B, the gutta-percha covering the wires.
C, the four wires through which the message is sent.

Mr. Whitehouse, of Brighton, by means of a similar arrangement, succeeded in making a piano write the music played on it. We have often used an harmonium so arranged, with a wire from every note, reaching to a telegraph arrangement placed several feet off, and on which each note as we played was accurately printed, both as to its position on the staff and its value as to time. Afterwards the calico strip might be used and played from, just as is done with printed music. By this instrument a composer could instantly print his most rapid musical effusions.

We have thus endeavoured to give you a general idea of the working of the electric telegraph. We might have extended the subject, and led you to experiments illustrating the application of voltaic electricity to the production of power. In doing so, however, we should have far exceeded the plan which we at first proposed. Indeed, the most costly experiments in this department of scientific application have all hitherto resulted in failure, and we have yet to wait until some fresh discovery shall place at our disposal a cheap means of obtaining electricity, and also enable us to overcome other difficulties, which at present oppose our progress.

We trust that our young friends will have arrived at some knowledge of this most interesting of sciences, in repeating the experiments we have offered. If you occasionally fail in your attempts, we can only recommend you to follow the example of the insignificant insect, who, despite the number of times her net may be broken, yet courageously repairs the rent. The perseverance of the little spider raised a king from a dungeon to a palace, by the force of example; and our wish is, that our young friends may lay to heart the lesson of determination which is involved in the anecdote to which we have only just alluded, remembering that "perseverance overcomes all difficulties."

Fig. 13.



TELEGRAPH NEEDLE AND ITS COIL.

EXPERIMENTS IN HEAT.

In our previous remarks we have stated that there were only a few forces in nature employed to produce the almost infinite variety of changes we observe in our daily experience. Two of these, electricity and magnetism, we have already considered; and we shall now give a number of experiments in connexion with another force, namely, that of *Heat.*

We are utterly at a loss when we attempt to answer the inquiry, "What is Heat?" We only know it by its effects. Some have supposed that all the forces are simply what they have termed "affections of matter;" or, in plain English, they say that heat is due to the motion or vibration of the particles of which any body is composed. Others consider that heat and light have an independent existence;—that they are quasi-material, and can be moved and measured as water, &c. It is sufficient for us simply to examine into the *effects* of these forces, and we shall therefore not lead you into the mazes of theory.

We will first suggest experiments showing the production of heat, and then pass on to consider other interesting matters relating thereto.

The Production of Heat by Friction.—There are so many illustrations of this in daily life, that we need only name them to make you at once aware of them. The striking of a common lucifer match, the heating of the axle of a cart or a railway carriage, boring cannon, &c., are all cases in which heat is produced by friction. Even heat may be produced by rubbing two pieces of ice together. The following is a simple experiment, showing the same result.

EXPERIMENT 1.—Rub a common knife on a stone for a few moments, and place it on a piece of phosphorus. This will immediately ignite, owing to heat produced by *friction.*

EXPERIMENT 2.—*Heat produced by Percussion.*—Hammer a nail smartly for some time on an anvil, and then touch a match with it. It will be inflamed.

Percussion caps are made so as to afford heat by percussion. The hammer of the gun falls on the back of the cap, and by sudden compression, the fulminate of mercury contained inside produces the heat required to ignite the gunpowder.

We have already adduced a vast number of experiments in which heat is produced by chemical action. Such instances show us that heat may be produced from gases, liquids, and solids. We add one more, which is curious from our having in the mixture all three states; namely, the gaseous in the ammonia, the liquid in the water, and the solid in the sulphur; and another where heat is got from ice.

EXPERIMENT 3.—Mix together iron filings, sulphur in powder, and a solution of sal-ammoniac in water. Make these into a paste, by pressing them together, by means of a piece of iron or a knife. Great heat may thus be produced; and if large quantities are thus mixed and buried some depth in the ground, the heat will become so intense that the mixture will ignite, and produce an artificial volcano.

EXPERIMENT 4.—Put a small piece of potassium into a hole in a piece of ice; the water of the ice will be immediately decomposed, and heat and light be afforded.

EXPERIMENT 5.—*Heat produced by compressing Air.*—If common air is suddenly condensed by means of a syringe on a piece of tinder, sufficient heat will be produced to set the tinder on fire. This experiment requires a little tact, but a few trials will enable our young friends who possess a syringe to succeed.

Heat produced by Combustion.—The instances of this are so numerous that we need not name them. We have already remarked that animal heat, and the heat produced in our furnaces, alike proceed from the same cause. The food is converted, in the animal, into blood, and its charcoal being conveyed in the blood to the surface of the membrane of the lungs, is there burned just as coals are consumed on the bars of our fireplaces. It is no exaggeration to say that we are walking stoves, our lungs the furnace, our food the coals, and the throat and mouth the chimney by which the human smoke, carbonic acid, escapes. To maintain the heat of our bodies, we require, in cold weather, an extra supply of charcoal in our food.

EXPERIMENT 6.—*Constancy of Animal Heat.*—If you place the bulb of a thermometer in the mouth, either in summer or winter, you will find that the temperature is always the same—namely, about 98°. This is effected by means of what we may call the safety-valve of our system, insensible perspiration. The skin is continually carrying off heat from our bodies; and just as the external air increases in temperature, so, in most cases, does the proportion of water given off by perspiration, keep the temperature of the body equal, by abstracting heat at the same time.

A singular experiment was tried some years ago, in which a man having been varnished all over, except a portion of the forehead, was placed in an oven heated to above 212°. The perspiration rushed in torrents from the unvarnished part, and so kept up the evenness of his bodily heat. We have, when lecturing in front of the hydro-electric engine, at the Polytechnic, Regent-street, lost in weight upwards of two pounds, owing to the rapid perspiration kept up for about an hour, and which was produced by the heat of the steam-boiler, together with the exertion of speaking.

We refer you to our electrical experiments generally, for instances of the production of heat by electricity, and need not remind you, that the great source of light, life, and heat, is the sun, to whose rays we are indebted for all the beauty and animation of our existence.

LATENT AND SENSIBLE HEAT.

In our previous remarks and experiments we have been showing how heat or, as it is sometimes called, caloric, is obtained from any body with which we are surrounded. Everything contains heat; but you will at once reply that our senses do not make us aware of this. Now, hence arises the distinction between *latent* and *sensible* heat. The word *latent* simply means *lying-hid*, and thus the heat we obtained in our past experiments existed in the materials we used, in a *lying-hid* or *latent* state, and only became *sensible* to our feelings when we used friction, percussion, chemical action, &c., to bring it forth.

On reflecting on these facts, our young friends must bear in mind that everything is continually absorbing, or giving off heat; and thus in the experiments we have made, we have merely got back a portion of the heat which our materials had received from the sun's rays, or from other sources, and retained in their substance until we called the heat forth for our purpose.

By the addition of sensible heat to a solid body, we are able to convert such into a liquid; in fact, the three states of all matter, viz. the solid, liquid, or gaseous, are dependent on the quantity of heat in bodies. Thus, in the case of frozen mercury we have a solid; in its ordinary state we find it liquid, and by boiling it we shall obtain it in a gaseous state; the two last resulting simply from a continued application of caloric, or heat.

It is believed that every solid can be converted either into a liquid or a gas, and the few exceptions to this are due to our want of sufficient heating-means to effect our purpose.

The effects produced upon bodies to which heat is applied, are chiefly those of Expansion,
Liquefaction,
Vaporization, and
Evaporation,
and we will by means of experiments investigate each of these.

Experiment 7.—*Expansion.*—With a few exceptions, all bodies expand or increase in size by the addition of heat. This may easily be shown by making a small hole in a piece of metal, which shall exactly let in the end of a cold brass rod. If the rod is now heated, it will be so expanded as to be too large to fit the hole, and it cannot pass through until cooled down again.

Experiment 8.—*Liquids expand by the application of Heat.*—Fit into a Florence flask a cork, in which is fixed a piece of glass tube a foot long. Now fill the flask and half the tube with a little coloured water, and apply the heat of a spirit-lamp. You will find that the water will gradually rise in the tube, as it is expanded by the heat of the lamp.

For the same reason our kettles often let the water escape at the spout if they are filled too full. The heat of the fire expands the water, and thus the liquid escapes.

Thermometers are made on this principle, and in fact our last experiment affords you a rough one. If the tube used is long enough, you may observe that the water goes on expanding until it boils. Mercury is employed in preference to water because its boiling point is much higher, as we shall afterwards explain.

To make a Thermometer.—A narrow glass tube has a bulb *blown at one end.* This is filled with mercury, as also is a portion of the stem. The mercury is then heated until it entirely fills the tube, whose other end is then sealed. Two points are then marked on a piece of wood; namely, the freezing and boiling points of water. These are ascertained by placing the bulb in melting ice, and then in water boiling in a *metal* vessel, and the intermediate parts are divided into 180 equal spaces, commencing at 32 as the freezing, and ending at 212, or the boiling point of water.

These spaces are called degrees, and indicate the temperature of any body in which the thermometer bulb is placed. The scale is called after its inventor's name, Fahrenheit. Other scales are employed on the Continent, such as that of Réaumur, and also the Centigrade. The relative divisions in each scale are as under.

Fahrenheit.—	Freezing-point 32°.	Boiling-point 212°.
Réaumur.—	„ 0°.	„ 80°.
Centigrade.—	„ 0°.	„ 100°.

Our young friends should provide themselves with a thermometer, and have that portion of the woodwork cut away which surrounds the bulb, as this enables you to dip the bulb in any liquid of which you wish to ascertain the temperature. The scale may range from 30 degrees below zero, or 0, as it is marked, to 300 degrees, or a temperature considerably over that of boiling water. You will thus be enabled to ascertain the temperature of both freezing mixtures and the boiling points of solutions of salt, &c., as the further experiments we offer will require.

Experiment 9.—Dip the bulb of such a thermometer in a little water containing pounded ice. It will indicate a temperature of 32° until the whole of the ice has melted.

Experiment 10.—Place the bulb in a *metal* saucepan in which water is boiling. The temperature will remain constant at 212° until all the water has boiled away.

Experiment 11.—Dip the bulb of the thermometer in a mixture of snow, or pounded ice, and some common salt. The temperature will fall much below 32°.

Experiment 12.—Instead of employing water boiling in a metal vessel, repeat the experiment in one made of *glass*. You will now find the water does not boil until heated beyond 212°.

Experiment 13.—Test the temperature of the boiling point of a strong solution of common salt in water. It will be found to be higher than that of common water.

Experiment 14.—Although mercury is almost always employed in thermometers, still, in some experiments with freezing mixtures, a spirit one must be used, as, owing to the intense cold, the mercury would be frozen.

Experiment 15.—Place the bulb in a mixture of water and strong sulphuric acid. The heat produced will be far above that of boiling water, and will depend upon the relative proportions of the liquids you employ.

Experiment 16.—Test the temperature of the different freezing mixtures we named amongst our chemical experiments. They will vary from 32° to perhaps 40° below zero; that is, seventy-two degrees lower than the freezing point of water.

Experiment 17.—We have stated that there are exceptions to the rule of expansion on the application of heat. Fill a tobacco-pipe bowl with clay, and heat it red-hot in the fire: the clay will become smaller, and when cool, will readily drop out of the bowl. For this reason potters always make their articles considerably larger than the intended size, as the process of "baking" reduces them afterwards to the proper dimensions.

Pyrometers, or *fire measurers*, are made by adopting this principle; namely, the contraction which takes place on clay being strongly heated.

Water is a beautiful exception also. On being cooled, it gradually contracts until it arrives at a temperature of 40°. It then begins to expand until formed into ice. Hence ice is lighter than the same bulk of water in which it floats. But for this provision in nature, the beds of the Arctic Sea would ever remain solidly frozen. By virtue, however, of this expansion, the light ice breaks away from the large mass, and swimming on the surface of the ocean as icebergs, becomes gradually dissolved by the heat of the sun's rays and the surrounding air. By the same rule again, as the ice melts the water contracts, and thus descends, conveying with it heat to the subjacent ocean; the temperature is thus gradually raised, and the rigours of an Arctic winter dissolved. This is one of the most complete and most valuable provisions we find during our scientific investigations, and, if needed, might be produced as an absolute proof of the existence of an allwise Deity.

Experiment 18.—*Gases expand on being heated.*—This is easily shown by using the flask and glass tube as in Experiment 8. Half-fill the flask with water, and placing the finger at the end of the tube, invert it in a basin of water, then place the hand on the top of the flask. The heat communicated to the air will drive the water away into the basin. On removing the hand, the air will cool down again and contract; the water will rush in *by the tube and regain* its old place.

EXPERIMENT 19.—Fill a bladder with air and tie the neck tightly. Place it before the fire, and the air will be so expanded as to burst the bladder.

EXPERIMENT 20.—Make a balloon, by pasting together pieces of thin tissue paper, leaving a hole at the bottom, of about three inches in diameter. Blow into the balloon when it is dry, and when full of air introduce the flame of your spirit-lamp, taking care not to set the paper on fire. The heat of the flame will expand the air, and after a short time you may let go the balloon, and it will at once ascend, because the air it contains is lighter than the atmosphere.

The earlier kind of balloons were all filled with heated air, and the temperature was maintained by means of fires. Serious accidents occurred, owing to the balloons catching fire, and eventually hydrogen gas was employed, as we have already described, under the head of "Hydrogen," in our Chemical Experiments.

We must here caution our young friends as to the common mode of sending up fire-balloons, by igniting spirits of wine placed upon tow. This is very dangerous, especially in the neighbourhood of haystacks and thatched cottages, to either of which they may set fire. We once saw the whole of the clothes in a garden, hanging out to dry, destroyed by one of these fire-balloons falling on them; and only a short time back, we witnessed a field full of new-made hay nearly destroyed in the same way. The best plan is that which we have named, or that of holding the neck of the balloon over the glass of a gas-flame.

EXPERIMENT 21.—*Ventilation.*—We succeed in ventilating our rooms, just in proportion as we bear in mind that hot air, being lighter than cold air, always ascends to the top of a room, and will there escape if there is any outlet for it. Our young friends may try a very simple, and, at the same time, a very instructive experiment. Place a lighted candle on the floor at the doorway of a room, with the door open. You will observe that the flame blows *into* the room. Now hold the candle exactly half-way between the top and bottom of the doorway; the flame will blow neither in nor out. Now raise the flame to within three or four inches of the top of the doorway, and you will observe that the flame blows *out* of the room.

Thus, cold air must be admitted at the lower part of a room, and an outlet made at the top for the escape of the hot and foul air, which rises upwards.

A very ingenious apparatus has been patented by Mr. McKinnell, of Glasgow, by which he admits fresh and gets rid of foul air by means of two concentric pipes, separated some little distance from each other. Its principle will be understood by the following experiments :—

EXPERIMENT 22.—Place a gas-jar over a small piece of lighted candle. In a short time the flame will be much decreased, and, although the top of the jar may be open, the candle will very likely be extinguished, for want of air. In such a case, re-light the candle, and now divide the top of the jar by means of a common card. A current of hot air will escape, and one of cold air descend into the jar, and complete ventilation of the inside of the jar be effected. The course of the two currents may be observed by holding a piece of smouldering brown paper over the neck of the jar.

EXPERIMENT 23.—The ascent of hot air in our chimneys is sometimes used for the purpose of turning the meat whilst at the fire roasting. The chimney-cowl rotates rapidly, and its motion is communicated by means of rods and teethed wheels to the spit holding the meat. Our young friends may make a very interesting illustration of this, which will form also a chimney-ornament.

Cut a card commencing from the centre to the outside, so as to form a spiral shape, and pull the card out so that it may appear like a long screw. Now hang it by its centre on a needle fixed in the cork of a bottle, and place it on the edge of a mantel-piece. If the fire is burning in the grate below, the hot air rising from the fender will make the card spiral to rotate, and as long as the heat rises so long will your card go round. The common chimney-cowl, and the ventilators often fixed in the doors of rooms, rotate from the same cause; that is, the ascent of hot air, or its passage through them.

EXPERIMENT 24.—The draught of a furnace-chimney is caused by the heat of the burning coals expanding the air passing through the bars, and thus making it to ascend the chimney. Rooms are often injured by the smoke refusing to pass up a chimney, owing to its sides being cold. This may often be remedied by lighting a piece of paper and holding it on the grate. The hot air thus produced ascends and warms the chimney, and cures its tendency to smoke.

EXPERIMENT 25.—Light some turpentine in a plate, and hold a glass tube, two feet long and an inch and a half in diameter, in an upright position in the flame; neither smoke nor flame will pass up. Now heat the outside of the glass tube by means of the spirit-lamp : a current of hot air will be produced up the tube, and the flame will roar up it with great vigour. This experiment will at once explain to you the reason why the paper burning in the grate, under a smoky chimney, has the effect named in our last experiment.

The effects of expansion by heat are largely taken advantage of by us in daily life. We have just instanced the case of our chimneys, &c. The blacksmith, by heating the iron tyres of the wheels, than which they are made a little smaller, causes them to expand and become large enough to pass on to the wheel. On being placed in position, the iron is rapidly cooled by throwing water upon it; it thus contracts, and is tightly bound on the wheel by these means. The cranks of steam-engines are sometimes fastened on the shaft by similar means.

Liquefaction.—We have already mentioned that most bodies can be changed from the solid to the liquid state, by the application of heat; and in our Chemical Experiments, and also under the head of Voltaic Electricity, we have named a large number of instances in which this takes place. We might mention here that every body has its own special affinity for heat, and this has given rise to the doctrine of specific heat. We shall, however, omit to discuss the subject as one more fitted for advanced students.

Solids differ very much as to their point of liquefaction, or becoming liquid. Mercury is always liquid at common temperatures, whilst water is a solid at 32°; and other substances do not melt until heated far beyond the boiling point of water. Pure spirits of wine cannot be frozen, and platina can only be melted by means of the oxy-hydrogen blowpipe, or the voltaic battery.

The chemist often takes advantage of heat in promoting the solution of bodies in water. Generally, most substances are more soluble in hot than in cold water, and some vary greatly in this difference of solubility; lime, plaster of Paris, and common salt, are exceptions to this rule.

EXPERIMENT 26.—Crystallization is carried on by dissolving salts in boiling water, and allowing the solution to cool, when the salt, insoluble in cold water, is deposited in the form of crystals. This may be illustrated by dissolving in boiling water as much of each of the following salts as it will take up; namely, sulphate of copper, and sulphate of iron. The vessels containing the solutions should then be set aside to cool, when crystals of each salt will be produced.

We have already instanced various illustrations of crystallization, to which we refer you among our Chemical Experiments.

Solution and fusion are terms which signify the reduction of any body from a solid to a liquid state, but the former is generally employed in reference to the action of liquids on solids, such as the solution of sugar in water, and fusion is mostly used to explain that action where heat is applied directly to the body which is to be converted into a liquid, as, for instance, the melting of lead in an iron ladle.

Experiment 27.—Chemists often use what are called fluxes, for the purpose of hastening the melting of a body. Thus, pure flint is scarcely to be melted by itself, but by adding to it four times its weight of carbonate of soda, and heating it in a crucible, it is melted with ease. The flint must first be reduced to a powder. Powdered glass, or fine sand, will answer equally well.

VAPORIZATION AND EVAPORATION.

We shall now direct your attention to some experiments wherein heat will be employed for the purpose of converting solids or liquids into gas or vapour; and we should here state that a gas differs from a vapour, in that the former is always gaseous at common temperatures, whilst vapour is only such when sustained by high temperatures. Thus coal-gas is properly what we would term a gas, and the steam rising from boiling water is a vapour. Clouds are another illustration of vapour, although they exist at a lower temperature than does steam.

The mode of producing steam from water is of course familiar to everyone; but we must bear in mind that every liquid does not produce vapour, or, in other words, does not *boil* at the same temperature.

Experiment 28.—Place a thermometer in a tin saucepan, in which a little spirits of wine is boiling. It will be found that the spirits boil at a temperature below that required to boil water. Ether boils at a still lower temperature, namely, at 96°.

In trying this experiment, take care that the vapour of the spirits of wine does not ignite. Should this happen, do not attempt to extinguish it by means of water, but place a small piece of carpet or flannel over the top of the vessel.

Experiment 29.—Water, spirits of wine, and ether, all boil at lower temperatures when the pressure of the air is removed. This can only be tried by means of an air-pump. The liquid is placed in a watch-glass, and the air pumped out of the receiver.

Experiment 30.—To boil water after it has been removed *from the fire.* This succeeds by your forming a vacuum in the vessel by condensing the steam. To do this boil some water in a flask, and when the steam issues rapidly cork the neck of the flask tightly, and instantly dip the vessel in cold water. The water will commence to boil again owing to the removal of the pressure of the air, and will continue to do so for some little time.

EXPERIMENT 31 —*Evaporation produces Cold.*—Whenever a liquid boils, its vapour carries off heat with it; and thus by placing a little water in a watch-glass, and resting another watch-glass in it containing ether, and exhausting the air from a receiver containing these, the water will be frozen, owing to its heat being taken away by the boiling ether. This plan has been used to obtain ice in hot countries; and a friend of ours is now constructing a large machine which will be thus employed in the West Indies for the purpose of procuring ice on the large scale.

EXPERIMENT 32.—Fill a garden-pot with water, and place a thermometer therein. The pot should now be put in any place where a draught of air is passing. The air will abstract the heat from the water in the pot, owing to evaporation going on on its outside, and the mercury of the thermometer will fall several degrees.

EXPERIMENT 33.—Tie a piece of rag on the bulb of the thermometer, and moisten it with ether. If you now blow on the rag, the mercury will immediately show a decrease of temperature.

For this reason we feel cooler when the air is blowing hard. The evaporation of the moisture of the skin carries off the heat of the body. In the Arctic regions, the most intense cold can easily be borne if the wind is still, but during a breeze the effect on exposed parts of the body is very severe, owing to the rapid evaporation produced.

EXPERIMENT 34.—The air always contains water in the state of vapour when its temperature is above 32°. To prove this, place a tumbler on a grass-plot in the sun, with its mouth downwards. The inside will soon be covered with dew, which is the moisture condensed from the air.

EXPERIMENT 35.—This may also be shown by placing a glass jar on a table, mouth downwards, and wetting the outside continually with ether. The moisture of the air will be deposited inside the glass.

Thus clouds, fogs, and rain are produced by the condensation of the moisture in the air. The vapour rises from the surface of the earth, and eventually being condensed by the cool air in the upper regions, is again sent to the earth in the form of rain.

The dampness of the walls of our churches and houses is due to the same cause. The cold walls condense the moisture found in the air.

Experiment 36.—Distillers take advantage of this law in producing spirits. Into some sugar and water, at a temperature of 60 or 70°, put a little yeast. After leaving the mixture to ferment for a few hours, pour it into a small tea-kettle to which you have fixed a yard or two of pewter tube fastened to the spout. Place the lid on the kettle, and put a little putty round its edges, to make it air-tight. Now heat the kettle over the fire, or by means of a gas-flame or spirit-lamp. When the liquid boils, the spirit produced has its vapour condensed in the pewter tube, and by receiving the liquid in a glass you may detect the spirit distilled over, by its taste. Keep the pewter tube cool by covering it with a rag wetted in water.

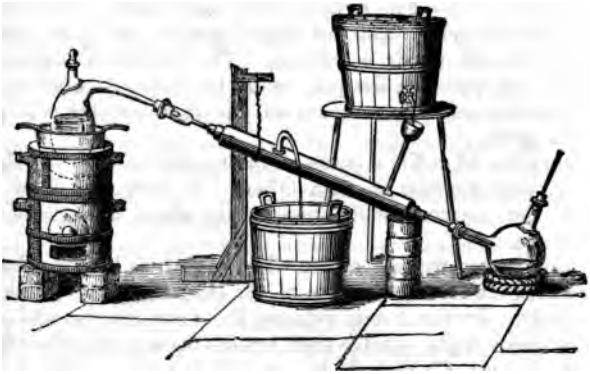


Fig. 1.

Fig. 1 illustrates a very neat mode of distilling liquids, wherein we observe on the left side a vessel containing the fluid, with a furnace beneath it ; in the centre is a large tin tube, containing one proceeding from the retort. This tin tube is continually supplied with cold water, which enters at the lower and leaves it at the upper part. On the right-hand side is a vessel which receives the condensed liquid. The steam rising from the retort, passes into the inside tube, and is there condensed into the liquid state.

In the ordinary process of distilling spirits from malt, &c., stills of large size are used. They are generally made of copper, *and set in a furnace.* From the top of the still, called its dome, a pipe proceeds which ends in a worm. The worm is fitted in a large vat, which is continually filled with cold water. As the water in this becomes heated, it overflows at the top, and runs away. The still is filled with the "wash," as it is called, and on heat being applied the spirit evaporates. Its steam or vapour is condensed in the worm, and it is collected in any convenient vessel. We are indebted to a friend for the following engraving, from which you will at once be able to follow the process we have described, and we shall therefore omit to detail each separate part. (See fig. 2.)

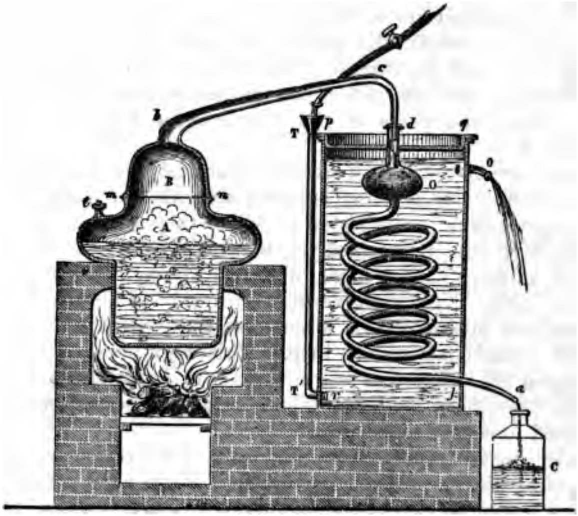


Fig. 2.

Sugar is boiled at a temperature much lower than is otherwise required, by means of a vacuum-pan, or just such another arrangement, only on the large scale and formed of copper, as that we spoke of in our experiment of boiling water after removal from the flame. (See Experiment 30.) Pharmaceutical chemists prepare decoctions of sarsaparilla, &c., by similar means.

Experiment 37.—We have often mentioned distilled water in our Chemical Experiments. It may be obtained by the same apparatus as that described in Experiment 36, by merely filling the kettle with water, and keeping the pewter pipe cool. Indeed, by fitting a piece of pipe, three yards long, to the spout of a tea-kettle on the fire, you may readily obtain distilled water, the length of the tube generally serving to condense the steam. Receive the water in a clean glass vessel.

STEAM AND THE STEAM-ENGINE.

The most interesting application of heat is certainly that of the steam-engine; and as the subject is so very extensive, we shall only endeavour to illustrate some facts about steam, and leave you to study the details, in such works as Professor Macquorn and Rankine's, from which you may learn all particulars; and also refer you to our section on "Pneumatics," where the parts of the steam-engine will be separately explained.

There are two classes of steam-engines employed, and they are called high or low pressure engines, according to the pressure on each square inch of the piston at which the steam is used.

We have already referred you to the fact that the air presses on all surfaces with a force of nearly fifteen pounds on every square inch. Now high-pressure steam is produced in strong boilers, and presses with a force sometimes equal to a pressure of 100 pounds per square inch. This high-pressure is chiefly employed in locomotive engines, and in land, or, as they are called, stationary engines, when sufficient water cannot be obtained to condense the steam.

Low-pressure steam—that is, steam not exceeding above a few pounds in its pressure beyond that of the air—is employed, with scarcely an exception, throughout Great Britain, for the purpose of propelling our steamboats. After the steam has done its work in the high-pressure engine, it is blown off into the air, as you will have observed in watching a locomotive engine running on a railway.

The steam of the condensing-engine is condensed, or returned to its old state of water; and here we may tell you that by heating a cubic inch of water, it can be turned into steam which will take up 1700 times as much space as the cold water did. On applying cold water, or (which is the same thing) condensing this steam, it loses its bulk, and is restored to its former small space of one cubic inch,—that is, an inch wide, deep, and high.

EXPERIMENT 38.—To illustrate the action of the low-pressure engine, have a bulb blown at the end of a piece of glass tube, six inches long and half an inch wide. Take a cork that will nearly fit the tube, and attach to it a piece of stick; twist round the cork a little cotton-thread, and soak it in some olive oil, and then fit it into the tube, so that it will easily move up and down, air-tight throughout its length. Now put a little water into the bulb, and having boiled it by means of the spirit-lamp, remove it for an instant from the flame and insert the cork and stick, until the former rests just above the edge of the bulb.

If you now place the bulb again over the spirit-lamp, the expansion of the steam will drive the cork to the top of the glass tube. Instantly on this occurring, dip the bulb into cold water; the cork will then be driven down to the bulb, owing to the condensation of the steam. By again heating the water, the steam will drive up the cork; and on condensing the steam again, the cork will be again sent down.

Now, on exactly similar principles, the condensing-engine is constructed, only that the steam is used on both sides of the piston, and the used steam is condensed in a separate vessel.

Experiment 39.—Have a cylinder of very thin tin-plate made, and at one end fix in a stopcock. A thin tea-canister will do, if you get the smith to solder on the lid, and the stopcock in it, so that every part shall be air-tight. Put a little water through the stopcock into this vessel, and boil the water until steam issues in abundance from the cock. Close this, and now pour cold water on the vessel; the steam will instantly condense, and the pressure of the air outside will be so great as to completely crush the sides and crumple the vessel up. This experiment is a very instructive one, for in one arrangement you have illustrated the production and condensation of steam, and the fact that the atmosphere presses on all sides with great force.

Steam-boilers vary in their construction, according to the purposes for which they are used. In manufactories, long iron boilers are used, having one tube through their centre. In locomotive and steam-vessel boilers, sometimes a thousand tubes are placed, through which the hot air of the furnace rushes. Each boiler is supplied with a safety-valve, whose use is, to allow the steam to escape into the air when the pressure is greater than it should be. Neglect of this valve has been the cause of numerous accidents, the boiler of course bursting when the steam exerts a greater pressure than the iron can bear. Beside the safety-valve is a water-gauge, by which the engineer can see that the water is of a proper height in the boiler.

The water is supplied by means of a pump attached to, and worked by the engine.

Steam has been largely employed for the purpose of heating factories and other places. It has several advantages over other means. In cooling down again to the state of water, steam gives out four times as much heat as its temperature indicates; for whilst it was being formed from water, it has taken up the heat in a latent form, and returns this when it is again condensed.

CONDUCTION OF HEAT.

We now invite you to a number of experiments which will give you some idea of what is called the conduction of heat, or the power which different bodies have of conveying heat through them.

Experiment 40.—You will at once remember that some things carry off heat faster than others. For instance, place an iron rod and a tobacco-pipe side by side in a common fire; in a very short time the iron rod will become hot to its end, whilst the pipe will remain cool.

In this case we call the metal a *good conductor*, because it carries the heat fast; and the tobacco-pipe stem is termed a *bad conductor*, because the heat passes slowly over it.

Generally speaking, the metals are the best, and such articles as wood, fur, dry air, and dry steam, are the worst conductors. The following experiments will show you, however, how much these differ from each other in their conducting power.

Experiment 41.—Twist together the ends of a piece of iron and copper wire, four inches long, separating their other ends two or three inches apart. Now place the *twisted* end in the flame of a spirit-lamp, and place a piece of bees'-wax at the further points of the two wires. You will find that the wax will be soonest melted on the end of the copper wire, owing to its being the best conductor. Hold the wire in the flame by means of a pair of pincers. Had you employed a rod of wood or glass, the heat would scarcely have passed through them; hence the use of wooden handles to teapots, to prevent the heat injuring the hand. Glass or wood handles are attached to urns for the same reason. In most steam-engines, the boiler and cylinder are surrounded with felt or wood, to prevent, by their non-conducting power, the escape of heat, and thus the fuel is economized.

Our clothing is also regulated by its non-conducting power. *Thus, in winter* we employ thick woollen garments in place of linen and cotton. They stand in order thus,—linen is the best, cotton next, and woollen and furs the worst conducting material.

Experiment 42.—Cover four tin cans with linen, cotton, woollen, and fur coats. Now fill the cans with hot water, and leave them for half an hour. If you try their temperature, you will find that the linen one has cooled most, and the fur one least. The other two will be intermediate to these.

Hence, in the Arctic regions, Siberia, and Lapland, thick furs are esteemed for their non-conducting power, enclosing, as they do, a large amount of air, which is also a very bad conductor. In the East and West Indies, and in Africa, linen and thin cotton garments are used for the contrary purpose.

Experiment 43.—"Cold feet" may be prevented by applying a fold or two of brown paper between the sole of the stocking and the sole of the boot. The paper is a bad conductor, and so prevents the escape of the heat through the leather of the sole.

The sense of cold that we experience on touching a metal, is owing to the rapidity with which the heat is carried away from the hand.

Experiment 44.—Place a little mercury in a hole in a piece of wood, and in one of iron, or any other metal. Introduce the bulb of the thermometer, and you will find that the temperature (in ordinary cases) will be the same. Yet the metal seems cold to the touch, by reason of its quick conduction of heat.

In very cold climates it is dangerous in winter time to touch a piece of metal exposed to the atmosphere. The effect on the skin is just the same as that produced by red-hot iron. In some of the Arctic expeditions the officers had their faces seriously hurt by allowing the metal of their telescopes to come in contact with the skin, which, under such circumstances, was severely blistered.

Experiment 45.—Liquids, generally speaking, are very bad conductors. They allow heat to pass only when their particles move; hence, nearly all our arrangements for boiling are so constructed that the heat should be applied at the *lower part* of the vessel. The bad conducting power of water may easily be shown by filling a basin with pounded ice and water. In this put a small copper basin, so that it may swim on the surface, and pour therein a little spirits of wine, to which set fire. The water under and next to this will soon boil, whilst all within an inch beneath it will be of a temperature not higher than 32°.

Whilst liquids are generally bad conductors, they sometimes, when raised to a state of vapour, become still worse; and by availing ourselves of this fact, we can offer two very amusing illustrations. In one we shall teach you how to handle red-hot lead safely; and in the other, to walk without danger on red-hot iron.

Experiment 46.—*To handle Red-hot Lead.*—To do this you must take great care to have the hand perfectly clean,—washing in soap and water will not do if your skin perspires very freely. You will observe that water, after you have thus washed, will run off the hands as if they were greasy, which in fact they really are. To pursue the experiment safely, melt some lead, say ten or twelve pounds, in a ladle, and make it *red-hot.* Now pour into a basin about a pint of strong liquid ammonia, and have in front of you a tub of cold water, into which the metal is to be thrown. When an assistant has brought the red-hot lead from the fire, dip your right hand into the ammonia and wash it well. Now dip it deep into the ladle of melted lead and throw the lead into the tub. Repeat this until most of the lead has been cast away, taking care not to touch the ladle with the fingers.

We have repeated this experiment over one hundred times, and the only sensation produced is that of cold, provided the metal is well heated. Never attempt the experiment unless the metal is red-hot, for all depends on a skin of steam being formed between your hand and the lead. On one occasion, our assistant did not believe in our philosophy, and brought the metal to the table at too low a temperature; the result was that one or two fingers were severely burned.

It only requires a little nerve for the first attempt. We must confess, however, that although we have exhibited this experiment before numerous audiences, we have not succeeded in persuading any one to repeat it themselves. If the experiment is repeatedly done, the hand becomes covered with a kind of horny matter, which eventually wears off.

Experiment 47.—*To walk on Red-hot Iron.*—Coat the feet with a mixture of glue and treacle. When thus covered, press the feet on some rotten stone, which may be laid on the floor. Four pieces of red-hot iron are now to be placed on four bricks. You may, with the feet thus coated, walk over the red-hot iron with perfect safety. The rotten stone forms a coat of non-conducting material on the feet, which thus preserves them from injury.

By an application of these principles, a little water may, by means of sulphurous acid, be completely frozen in a red-hot platina crucible; but as our young friends may not be prepared [illegible] *go to* the expense required, and as they can scarcely be ready enough to manipulate carefully, we shall not further allude to this than by mentioning the fact.

Some substances being bad conductors, have lately been employed to fill cases surrounding fire-proof safes. An experiment will illustrate the principle.

EXPERIMENT 48.—When the kettle is boiling, remove it from the fire, and hold it by placing the hand under the bottom. The non-conducting power of the charcoal deposited on it will entirely prevent the hand being injured.

By the experiments we have suggested, you will have become acquainted with the reason of many interesting occurrences in daily life; but we shall hint at a few which may not at first be so apparent. Snow is a bad conductor, and so prevents the heat of the ground from passing away. In Arctic regions snow houses are always used; and we assure you that they are far warmer than a brick one would be. In these the Esquimaux eat, drink, sleep, and cook their food, using whale oil for the purposes of obtaining light and heat.

In removing ice from wells, the ice is always wrapped in blankets. Now, this seems strange, but allow us to remind you that it is for the very same reason you use blankets in bed. In either case the wool is a bad conductor of heat.

If the mould of our gardens was solid, like clay, the plants would be starved by the better conducting-power which clay has over loose mould. The latter encloses air which, in fact, keeps the roots of the plant warm.

Gutta-percha is a far worse conductor than leather; and by walking over the pavement covering a baker's oven, you will perceive the heat at once to pass through the leather, whereas gutta-percha soles prevent its passage.

In making tea, if the pot is covered with a woollen cloth, the tea infuses better, and is much stronger than that made in the usual fashion, because the heat is retained by the non-conductor you place over it.

Floor-cloth often produces cold feet, because it rapidly carries away the heat. Carpets have not this effect, and a peculiar kind of floor-covering called "Kamptulicon," which is made of india-rubber and cork rolled together, will not permit the feet to get cold for a very long time, although you may be sitting quite still. The floors of the Houses of Parliament were covered with this material some years ago.

The outside bark of a tree is a worse conductor than its wood, and so is our skin than the flesh. In each case the life-heat is prevented from passing too rapidly away.

But we need not multiply these instances. The exercise of observation on your own part will be sufficient to make you acquainted with numerous instances continually occurring in your daily experience.

RADIATION, ABSORPTION, AND REFLECTION.

We are all familiar with the fact that some bodies, when exposed to the sun's rays, become hot quicker than others. This is owing to their power of *absorbing* heat. Such bodies generally cool quickly, and that is because they *radiate* or send off the rays of heat rapidly. Others, such as polished metals, *reflect* heat, and scarcely become warm, even when exposed to large fires or the scorching heat of the sun. Such are called reflectors, because they throw from their surface the rays of heat, and but slightly absorb or radiate them.

Experiment 49.—Place in the sun's rays a polished tin can, and another which you have painted with lamp-black. Fill them with water, and put on their covers, so as to prevent any change owing to heat escaping from the water. Test their temperature by means of the thermometer in an hour's time. You will find that the polished one has scarcely become warmer, because it is a good *reflector*, but a bad *absorber*. The black one, however, being a good absorber, will be found to have heated the water considerably, because it has drawn in the heat from the sun's rays.

Experiment 50.—Expose the polished and black cans full of water, in the open air on some night when the sky is quite clear. Ascertain the temperature of the water first, and again after an hour's time. You will find that the black can has lowered in temperature, owing to its being a good *radiator*, whilst the temperature of the polished can has scarcely changed.

Now, for this reason, we find that in the sun's rays a black coat makes a person hot, because it absorbs heat. The same coat if worn at night under a clear sky, will make a person feel cold, owing to its being a good radiator; and thus, generally speaking, good radiators are good absorbers, and *vice versâ*. White garments are used in summer time, because they do not absorb heat so rapidly as do dark ones.

Experiment 51.—Place the hand on the glass of a mirror which has been long exposed to the sun. It will be cool, because it is a good reflector. If the frame is made of dark wood, it will be found quite hot, owing to its having absorbed the heat *rapidly*.

Thus, in passing in summer between walls which have been whitewashed, you will find the air cool; whilst walls which have been painted black throw off so much heat as to make the air very hot.

Polished tin is employed to line meat-screens, and so to reflect back the rays of heat passing from the fire on to the meat roasting before it. Ovens have been constructed, which, placed before the fire, will allow of both sides of a piece of meat to be baked at the same time, by adopting this principle.

Experiment 52.—Dew is formed by the radiation of heat from the earth's surface during a clear night. Place a piece of white cloth on a grass-plot; on examining it next morning you will find all the grass which has been exposed wet with dew, whilst the covered part will be quite dry. Thus dew is not produced on a cloudy night, owing to the clouds preventing radiation, just as the cloth will do.

Experiment 53.—Dew is deposited owing to the cold produced by radiation condensing the moisture contained in the air near the surface of the ground. To prove this, place a thermometer on the ground and another one a few feet above it; you will find the lowest thermometer indicates a temperature several degrees cooler than the one raised over it.

Experiment 54.—Vessels which are good radiators lose heat quickly. Fill the polished and black tin cans mentioned in our previous experiment with boiling water, and note their temperatures in half an hour's time. You will find that the black one has lost most heat in the same time, owing to its good radiating power. You must not place these vessels in the sun for this experiment, because that would interfere, by allowing the absorption of the heat of the sun.

Tea-pots, if they are kept brightly polished, keep tea longer hot than dark earthen ones; and whilst it is essential that the top of the kettle should be kept bright, to prevent the rays of heat escaping, the bottom should be black, so as to absorb those proceeding from the fire. We omit to speak of the conducting-power of the charcoal, for which see Experiment 48.

If you spend a night out at sea on board a vessel, you will find the air much warmer than it would be on shore, because the level surface of the water radiates no heat. On approaching the land—as, for instance, on entering any of our rivers from the sea at night—the air soon begins to feel cool, owing to the radiation of the earth's surface.

By means of reflectors heat may be collected and thrown on to any surface, just as light is by means of concave mirrors. By using two of these a mutton chop has been cooked at a distance of ninety feet from the source of heat. This and many other applications of heat we must pass over, for want of space, and shall only add one more which has lately caused considerable interest in scientific circles.

We are indebted to J. J. Griffin, Esq., of Bunhill-row, London, for the following illustrations of a most ingenious and novel mode of producing an intense heat by means of a mixture of air with common coal-gas, which he has made the subject of a patent.

Our young friends will remember that we stated in our Chemical section, that just in proportion as we could urge rapidly oxygen gas on a burning body, so the quantity of heat produced was increased. Mr. Griffin, by means of bellows which drive air through a peculiar arrangement, has succeeded in making a furnace which, although occupying a very small space, has sufficient heating effect to melt cast iron with great ease.

Our illustration (fig. 3) will give you an idea of this arrangement when in use. On the right is the gas-furnace placed on a table; in the centre we have the bellows which supply the air blast, driven by a man who at the same time can superintend the entire operation.

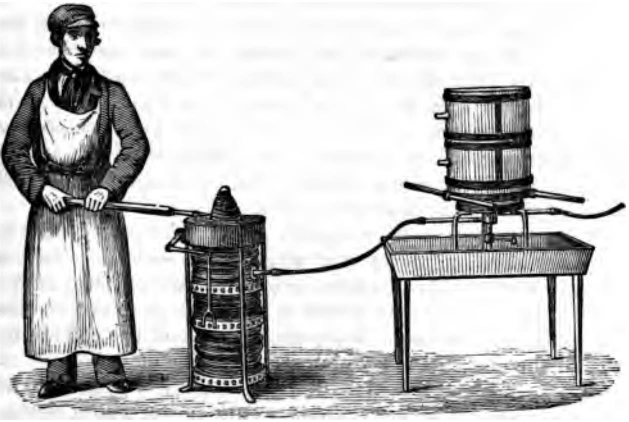


Fig. 3.

Our next illustration will assist you to understand some of the internal arrangements of the furnace (see figs. 4 and 5).

Fig. 4 is that portion through which the air and gas pass together. Fig. 5 shows the holes at the top of fig. 4, which only represents them in section. These, in fact, form the heating portion of the furnace.

Mr. Griffin has adopted two different methods of applying heat. In some cases he prefers to drive the heat downwards; in others the heat is applied from beneath. The following engravings illustrate the plans by which the heat is applied from above.

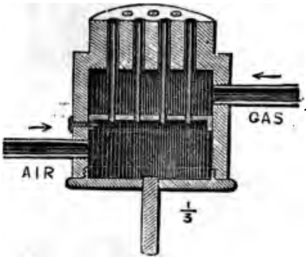


Fig. 4.

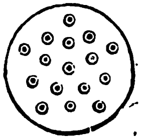


Fig. 5.

Gas Furnace heated at the Top, exhibited in Section by fig. 6. —*a* is the gas-burner; *b* is the support for it, when used below the furnace; *c* is the iron tripod support for the furnace; *d*, *d*, are two perforated clay plates, adapted to the gas-burner, *a*; *e*, *e*, are two clay cylinders.

The interior of the furnace, as represented by fig. 6, is built up as follows:—The clay plate, *d*, is put upon the tripod, *c*. Over the central hole in *d*, the clay cylinder (fig. 7) is placed, and upon that cylinder two or three of the clay plates represented by fig. 8. Upon these a porcelain or platinum crucible is placed. If it is of platinum, a piece of platinum-foil may be put between the crucible and the uppermost clay plate, to protect the crucible from contact with particles of iron, or against fusion with the clay. The crucible is to be covered by the plumbago jacket, fig. 9. The space between this pile in the centre of the furnace and the two cylinders, *e*, *e*, which form the walls of the furnace, is to be filled with flint stones, or gravel, washed clean and dried. The stones which answer best are rounded, water-worn pebbles, of half an inch to one inch diameter. These may be piled up to the top edge of the jacket, fig. 9. The number of clay plates must be such as to bring the top of the crucible to the distance of two inches, or two and a half inches at the utmost, from the flat face of the gas-burner, *a*. In some cases, merely one of the furnace cylinders, *e*, is necessary, in which case the crucible and its jacket is placed directly upon the cylinder (fig. 7); and when only a moderate heat is required,

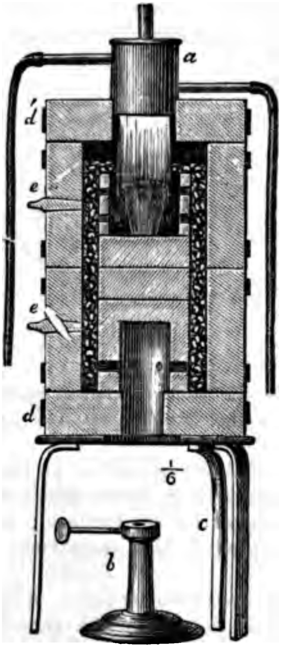


Fig. 6.

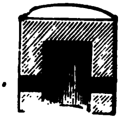


Fig. 7.

Fig. 8.

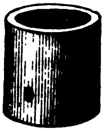


Fig. 9.

even the packing with pebbles may be dispensed with. Another means of diminishing the heat is that of increasing the distance between the gas-burner and the crucible.

In the above it will be seen that the gas-flame is driven by means of the blast directly on to the crucible. Our next illustration represents the other form of the furnace, in which the heat is produced beneath the crucible (see fig. 10).

The packing of this variety of furnace is performed as follows: The clay plate, *d*, is placed upon the tripod-stand. The crucible jacket, fig. 11, or one similar, but of larger size, is placed upon the plate, *d*. The crucible and its cover is then put into its place, and is covered with the dome, fig. 12, which must rest upon the lifter, *f*, and must be of such a width as to clear the *crucible easily* when lifted. The internal height of the dome should be such as just to clear the top of the crucible cover. Consequently, where crucibles of different sizes are used, domes of different sizes are also necessary. Observe, distinctly, that

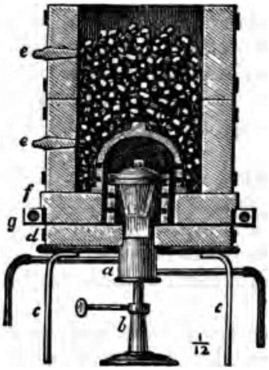


Fig. 10.

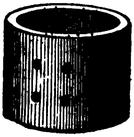


Fig. 11.

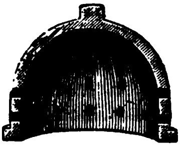


Fig. 12.

the crucible and its support are to rest upon the plate, *d*, and the dome upon the lifter, *f*. The furnace cylinders, *e*, *e*, are now to be superposed, and the space between the dome and the cylinders, and that above the dome, are to be filled with small pebbles, as already directed. The gas may then be lighted, the blast of air set on, and the operation be allowed to proceed.

Fig. 13 represents a plumbago crucible which is used to suspend the inner crucible over the gas-flame.

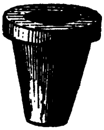


Fig. 13.

We have thus endeavoured to give you a general idea of this ingenious application of the laws of heat, and have freely availed ourselves of its inventor's own description.

Some of our readers may wish to be in possession of the results produced by the action of the furnace; we, therefore, give some particulars with which Mr. Griffin has favoured us.

Examples of Fusions effected by the Blast Gas Furnace.—The fusing points of certain metals have been fixed by Daniell at the following temperatures:—Silver, 1873°; gold, 2016°; copper, 1996°; cast iron, 1786°; brass, with 25 per cent. of zinc, at 1750°. All these metals melt readily in the gas furnace. Quantities of 3 lbs. of copper or cast iron can be completely fused in fifteen minutes in a six-inch furnace.

Quantities of 8 or 10 lbs. of copper or cast iron can be completely fused into a homogeneous mass in a six-inch or eight-inch furnace, within one hour, using a sixteen-hole burner, and a supply of gas from a half-inch pipe.

Choice of Crucibles.—The experiments above referred to were made with coal gas at the ordinary pressure, and with a blast of cold atmospheric air. Greater effects can be produced by the use of oxygen gas, or of heated atmospheric air. But a difficulty stands in the way of the use of these greater degrees of heat, in the want of crucibles capable of enduring their action.

With cold atmospheric air, pure nickel and pure iron dissolve every kind of siliceous crucible, and it is therefore needless to heat the air or to employ oxygen till a superior kind of crucible is obtainable. At present, these metals can only be melted in plumbago crucibles, which necessarily communicate to them more or less carbon.

Metals which melt at moderate degrees of heat, such as gold and copper, are easily fused either in clay or crucibles, or in those of plumbago; the latter, be it remembered, being a mixture of graphite and clay. Metals in combination with carbon, such as cast iron, also melt readily in clay crucibles, without destroying them. But when such metals as iron, nickel, and cobalt are free from carbon, and brought into a state of purity, they acquire an extraordinary attraction for silica at a white heat, so that the metal and the silica readily run down into a very fusible silicate. Even when plumbago crucibles are used, the carbon burns away at some particular point, the metal then attacks the clay, bores a hole through the crucible, and finishes the operation. No kind of clay or porcelain will withstand the action of pure iron or nickel at a white heat. It is therefore impossible to effect any large fusions of these metals when they are free from carbon, or when they are heated in crucibles that are free from carbon.

The following are a few of the uses to which this furnace may be applied, and we also mention some very beautiful results in the production of coloured flames, which may be obtained by it.

Miscellaneous Uses of the Blast Gas Furnace.—1. The preparation of chemical substances by the projection of mixtures into a crucible kept at a red or a white heat. 2. For melting silver, gold, copper, cast iron, brass, bronze, nickel-silver, &c., either for making small castings, or ingots. 3. For experiments on glass; every description of which it is able to fuse. 4. For experiments on enamels, coloured glasses, and artificial gems. 5. For experiments on metallic alloys. 6. For the fusion of steel.

7. For the use of dentists, in the preparation of mineral artificial teeth. 8. For the assay of ores of silver, copper, lead, tin, iron, and other metals. 9. For all purposes of ignition, combustion, fusion, or dry distillation, at a red heat, or a white heat, where it is desirable to produce those temperatures promptly, certainly, steadily, conveniently, and cheaply.

Exhibition of Coloured Flames.—When the gas-burner (fig. 4, p. 183) is supplied with gas and air, and a light is applied in the open air, so as to produce a clear blue flame of three inches long, and beyond it a flickering, nearly colourless flame, of twelve inches long, brilliant colours may be given to this flame by the introduction of concentrated solutions of certain salts. A ball of pumice-stone, two inches in diameter, fastened to a stout iron wire, is dipped into the saline solution, and while wet is plunged into the flame, upon which the whole flame becomes coloured. Solutions of the following salts may be used for these experiments :—

1. *Chloride of Strontium* gives a brilliant, crimson flame. 2. *Chloride of Calcium*, a reddish-orange flame. 3. *Chloride of Sodium*, brilliant yellow. 4. *Chloride of Copper*, bluish-green. If the flame is touched on one side with the copper solution, and on the other with the strontium solution, half the flame is green and half crimson. The colours and reflections of these flames are necessarily most brilliant in a dark room. A remarkable effect is produced by the common salt flame. It is reflected from the human countenance with a ghastly blackness.

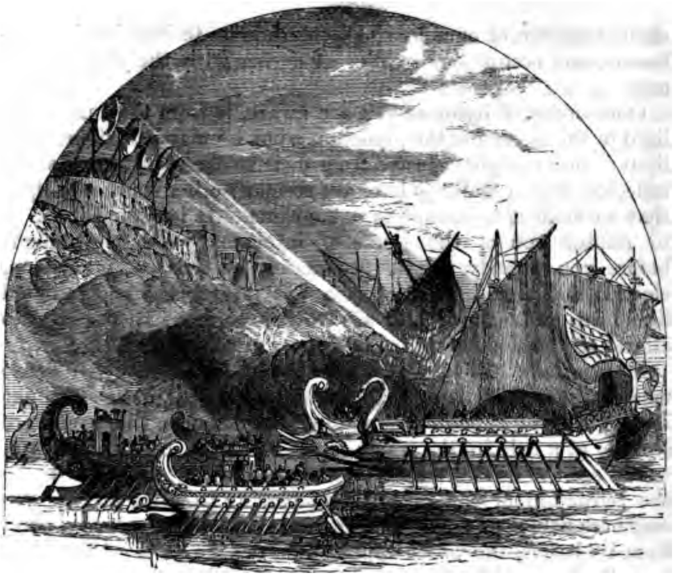
About five years ago Mr. Bessemer, of St. Pancras, London, succeeded, by employing an intense heat, produced by different means to those we have just described, in obtaining nearly pure iron. He uses a powerful jet of air, which is driven into the middle of melted cast iron, contained in a crucible. The oxygen of the air so supplied attacks the carbon in the iron. During the process a magnificent combustion takes place, and at its conclusion the metal is obtained in a malleable condition. Our young friends will find the usual mode of obtaining this result described under the head of "Iron," in our Chemical section, and they will not fail to remark on the greater simplicity of Mr. Bessemer's process.

Having confined our experiments to matters which we trust will interest you, we shall leave to your own ingenuity the further application of the different laws of heat.

It is an excellent plan when reading or experimenting in science to ask ourselves the question, "What is there in my daily life that owes its occurrence to this rule?" In your walks out endeavour to make science your companion. There is not a pebble, leaf, or flower which may not teach you valuable lesson. But its value will depend upon your inclin tion to learn from it.

Our most valuable scientific discoveries have not sprun always from the researches of those who have dedicated the lives to science. On the contrary, such men as Watt, Stephenso and many others, are examples of a successful struggle wit obstacles, many of which arose through their want of scientifi knowledge, and which they had to overcome by a determine but intelligent perseverance.

Many of the facts connected with the science of heat have relation to that of light. Our next section, therefore, will b devoted to the consideration of some of the most interesting law of Optics, and the various instruments and applications whic have been invented and are used in connexion with tha subject.



EXPERIMENTS IN LIGHT.

We now propose to deal with a branch of science and its applications which affords the most diversified and beautiful results. The familiarity which we all have with that wonderful agent, light, invests all our experiments with an interest and fascination which perhaps no other subject can afford.

Its numerous applications—as, for instance, photography, the microscope, telescope, the magic lantern, &c. &c.—will be an inducement which we are sure will stimulate our young friends to all earnestness in pursuing this subject, and we will promise them, that at comparatively little cost and trouble they may reap a rich harvest of amusement from the experiments we are about to offer.

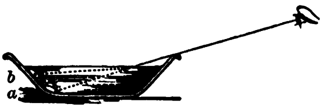
You will naturally ask, What is light ? and we must reply as we did before respecting heat, that we know nothing of it except by its effects. Some have thought it to be material, others suppose it to exist owing to the undulations of an ether (or, in plain language, a something we do not understand). We shall, however, at once leave all the *theories* to long-headed professors, and occupy our smaller capacities with the *facts* of the case.

One source of light, as you are aware, is from the sun. The light of the moon and the planets is what we may call "borrowed light;" that is, light reflected from their surfaces, just as we see it reflected from a wall. There are so many other sources of light that we shall not attempt to name them. It is sufficient for us to remind you of the scores of instances we have brought before you already, of its production by friction, percussion, electric and chemical action, &c. It is absorbed and radiated like heat, and, as we shall see further on, may be reflected to almost any extent by means of proper arrangements.

Experiment 1.—If a ray of light passes through a dense medium, it is, as it is called, "refracted,"—that is, the straight line of the ray is bent. Supposing, for instance, that you were looking at a fish in the water from the bank of a river: you would see the fish several inches from his real place, owing to the refraction of the rays of light passing from his body. We may here name one effect of refraction. On looking into a pond from its banks, the water appears of a depth one-third less than it really is; and in bathing you should allow for this, as you run the risk of a serious accident, by your making a mistake as to the real depth.

Experiment 2.—Place in a basin a penny, and just retire so as to only see the extreme edge of the coin. Now get a friend to fill the basin with water, and the whole penny will become visible. Fig. 1 represents this, where the dotted lines show the real and apparent place of the coin.

Fig. 1.



a, the real place of the penny.
b, its apparent position.

Experiment 3.—A straight stick placed obliquely in a pail of water will, for the same reason, appear broken.

It is owing to this refraction of light by our atmosphere that we obtain twilight; the colour of the clouds at the rising and setting of the sun; and that we also see the sun, as we think, some time before it really rises in the morning, owing to its rays passing into the air and being bent down, or refracted, to the eye.

Fig. 2 gives an illustration of the appearance of the sun to a spectator before it has really risen. The inner circle is intended

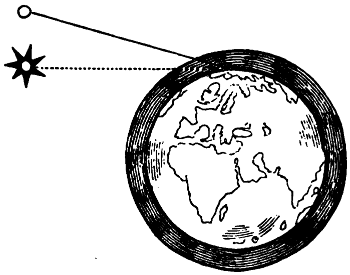


Fig. 2.

to represent the earth. The outer one the atmosphere. The upper line points to the sun's apparent position, and the lower one to its real place below the horizon.

The rays of light travel with great swiftness—in fact, at the rate of nearly 200,000 miles per second; and it takes about eight minutes for light to reach us from the sun. In other words, supposing we could place a screen on the sun's surface, and again instantly remove it, it would be about eight minutes after we lost sight of the sun before we should again see its light. Some of the fixed stars are so distant from us, that twenty years would elapse if one of them was suddenly extinguished, before we should be aware of the fact by the loss of its light.

Our young friends will be able to remember the speed at which light travels, when we tell them that it takes about one second to travel from the moon to the earth, a distance of about 200,000 miles.

Experiment 4.—In passing through a tunnel, if you observe the effect of a lighted cinder falling from the engine, you will find that the mortar of the bricks forming the sides of the tunnel is distinctly shown in every part. The moment the cinder is passed, the mortar seems to run past you in straight lines.

Experiment 5.—Tie a piece of red-hot wood to a piece of string, and turn it round rapidly in a circle. You will not see separate lights, because the eye can only take in a ray lasting not less than the eighth part of a second in passing to it. Fo this reason you observe the running lines we spoke of in ou last experiment.

Experiment 6.—Turn round the same piece of wood in dark room, and let a friend at the same time discharge a Leyde jar, so as to obtain a spark from it. You will now see th piece of wood at rest when the spark passes, showing how ver much more rapidly light travels than does the wood through th circle. This will explain to you how, in our previous observa tions, we were enabled to see every brick and piece of mortar i the tunnel, where the light travelling from the cinder so fa exceeded in rapidity the rate at which the train travelled in reaching the eye.

Experiment 7.—Colour may be produced by breaking up o refracting a ray of light. For this purpose let light fall on prism of glass; that is, a piece of glass having three sides You may obtain one of these from any glass-cutter; in fact pendant from a chimney ornament will answer the purpose Hold one of these so that the sun's light may pass through it and let the rays be received on a wall or sheet of paper. B placing the prism so that a ray of light may pass through i (see fig. 3), the light will be divided into three primary colours blue, yellow, and red. Besides these, other colours are visible

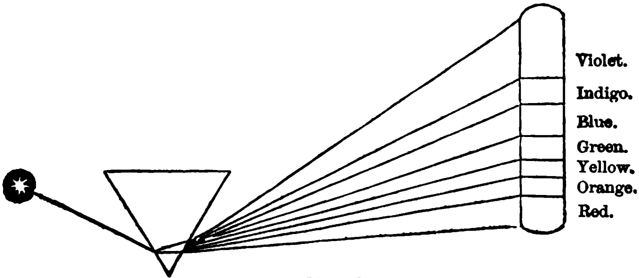


Fig. 3.

which are produced by the union of those we have named thus the ray on paper will appear to have in all seven colours as in our diagram above.

Experiment 8.—Place in any one of these colours, as receive on a sheet of paper, a coloured ribbon, or, in fact, almost an object. You will find that it will appear of the same colour a the ray in which you place it.

We learn from this, that what we call colour is simply owin to rays of light of that kind being sent to our eye which corresponds to a similar colour in the spectrum; and that the colour of the object may be changed so long as we retain the object in a ray of light of a different colour to that itself possesses.

By the word "spectrum," we mean the rays of coloured light as produced by the prism on the sheet of paper or other surface.

The rainbow is produced by exactly similar means. The rain-drops act as a prism; and dividing the white light which falls on their surface, send from each drop the different coloured rays just as our prism does.

EXPERIMENT 9.—Mono-chromatic, or single coloured light, is that which affords only one colour. We must here request you to try the following experiment:—

Dissolve common salt in spirits of wine, and put some of the solution on some tow or in a plate. Then set fire to it, and all surrounding objects will appear almost of the same single colour, if the experiment is tried in a dark room.

EXPERIMENT 10. — *Colour produced by Soap Bubbles.* — Blow a soap bubble in the usual way, and watch, as it increases in size, how great a variety of beautiful colours it presents.

EXPERIMENT 11.—A bottle in which you may produce these colours at any moment may be thus made. Put a little water into a Florence flask, and let it boil over the spirit-flame. When boiling drop into it a piece of Castile or shaving soap, of the size of a pea. Have ready a cork that perfectly fits the neck of the flask. When the soap is all dissolved, remove the flask from the flame, and instantly cork it, covering the whole of the top of cork and neck with sealing-wax, to keep it airtight. On cooling, you will find that if the soap and water are shaken up, some splendid rings of colour are produced across the flask, and of every hue. The advantage of this arrangement is, that as the flask contains no air, the soap-rings last much longer before breaking, than do the soap bubbles of our last experiment. A common bottle of any sort will do for the purpose if it is heated gradually.

EXPERIMENT 12.—Drop a small quantity of oil on water. Colours will be produced as in our last experiment. They are all due to the thin plates formed giving off colours such as we obtained by means of the prism. The thick plates afford red colours, and as the plates go on decreasing in thickness we have orange, yellow, green, blue, and lastly, when very thin, a black plate is produced.

EXPERIMENT 13.—Another instance of colour being produced by thin plates or lines is that of mother of pearl. To show that the colour of this is not in the pearl, take an impression from it by means of the best black sealing-wax. You will find that the fine lines are transferred to the wax, which will now exhibit a vast variety of colours on its surface.

Experiment 14.—Melt some lead in a ladle, and then clear its surface completely of dross; if you hold it in the light, you will observe beautiful colours formed, as in our previous experiments, owing to the various thicknesses of the oxide of lead produced on the metal.

Experiment 15.—To show how the variety of colours is produced, mix together different powders: thus, a red and yellow will produce an orange; blue and yellow, a green; blue and red, a purple. Chrome yellow, prussian blue, and red-lead may be used for this purpose.

In the same way you will find that the vast variety of colours produced in daily life by the dyer's art are due to the mixture of different tints.

An excellent effect in dress and decoration is produced by so arranging colours as to have near them what are called their accidental or complementary colours. Thus, gold looks brightest when contrasted with blue; articles of a red colour when placed near green ones. Those desirous of learning more of these subjects should consult a work by M. Chevreul on colour. The reason of this contrast will appear on your trying the following experiments:—

Experiment 16.—Look steadily for some time on a bright yellow-coloured piece of paper. On looking around you will find every object of a greenish tint.

Experiment 17.—Repeat this experiment by looking on sheets of various-coloured papers. The colour which then seems to invest other objects is the "accidental" one to that you have been intensely looking at.

Experiment 18.—Paint on a circular piece of cardboard the seven different colours named in our Experiment 7. They should be painted in the same order as represented in the spectrum; and the card may be placed on a pin at its centre. Make the card to spin rapidly round on the pin. The colours will now seem to unite and produce a greyish white colour. This is often shown at lecture tables for the purpose of producing white light from its various colours; and is, of course, the exact contrast to the experiment with the prism.

LENSES AND MAGNIFYING GLASSES.

Having thus by our experiments examined into the cause of *colour, we shall* now attempt to explain to you how lenses act, such as are employed in magic lanterns, telescopes, microscopes, &c.

Experiment 19.—Lenses are always made of glass for ordinary use, but for delicate microscopic purposes some have been made of the diamond and other precious stones. A very simple one may be made of water, by dropping one drop on a piece of window-glass, and holding the glass with the water-drop downwards. This will then assume a kind of circular form, as in fig. 4.

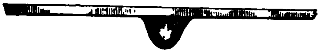
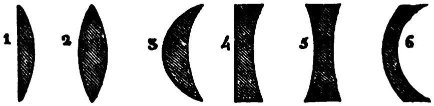


Fig. 4.

This simple affair really forms a good microscope, as we shall afterwards explain, and shows our young friends how easily some interesting branches of science may be studied.

The following diagram will give you some idea of the shape of different lenses.

Fig. 5.



1 is a plano-convex lens.
2 is a double-convex lens.
3 is a meniscus lens like a watch-glass.
4 is a plano-concave lens.
5 is a double-concave lens.
6 is a concavo-convex lens.

The focus of a lens is that point beyond the lens where all the rays passing through it meet together; thus the point A, in the next diagram, is the focus or focal-point of the rays passing through the double-convex lens. (See fig. 6.)

Experiment 20.—Hold a common magnifying glass in the sun's light so that all its rays passing through shall be focussed on a piece of black cloth, or the end of a lucifer-match;—either of these will be ignited. This will teach you how heat and light passing from an object may be collected together and thrown on one point.

Experiment 21.—Fill the bulb of a thermometer tube with water and place it in the focus, as in the last experiment. You will find that, although cloth and paper may be burned, still that the water will not become heated.

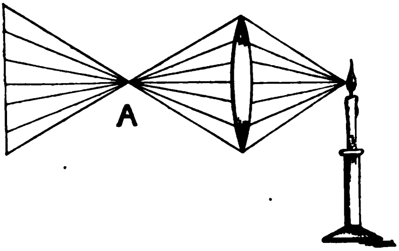


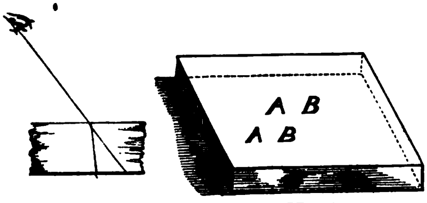
Fig. 6.

Lenses are used to magnify objects, or, in other words, to bring more rays to the eye than the eye can collect by itself; hence their employment in spectacles, telescopes, &c., of which we shall hereafter speak more fully.

In our past experiments we have simply dealt with a ray of light once refracted or bent by means of glass. We shall now introduce a substance by means of which we can produce what is called double refraction, or, in other words, we shall *twice* bend a ray of light.

Experiment 22.—Obtain a piece of Iceland spar, which you may do for a shilling or two at the optician's. Place it on a printed paper. The letters will all appear double on looking through the spar. In fig. 7, No. 1 illustrates the effect.

Fig. 7.



No. 2. No. 1.

No. 1 is a piece of Iceland spar, through which the letters A B appear double.

No. 2 illustrates the separated rays passing through the spar. *As we* shall have to speak again of this substance when referring to polarized light, we shall dismiss it for the present, and introduce a few experiments on the reflection of light.

REFLECTION OF LIGHT.

We see no object except by the "reflection," or "sending back," of the rays of light from its surface; and hence form, colour, size, &c., are impressed on the mind by the rays of light passing from an object and producing their effect on the eye.

We may here, to some extent, explain how it is that we see. To make ourselves understood, we must divide the eye into two parts, the black part, or pupil of the eye, acting as a lens, and the back and the invisible part, called the retina, acting as a screen to receive the rays passing through the front part of the eye.

In the eye of man but one lens is found, and by contracting or enlarging it we are enabled to suit ourselves in viewing distant or near objects. In the eye of insects, so many as 200 or 300 of these lenses are found. The fly's eye is a network of them, and presents a beautiful appearance under the microscope.

The retina of the eye is a kind of network ending in the seeing or optic nerve; and it is by means of this nerve that objects are recognised by the mind, and which enables us to connect the mental with the mechanical act of seeing.

But you will ask, how it is that, having two eyes, we do not see double? Sir John Herschell replies:—"It is a matter of habit. An object (a small globe or wafer suppose) is before us on a table; we direct our eyes to it—that is, we bring its image on both retinæ to those parts which habit has ascertained to be the most sensible and best situated for seeing distinctly; and having always found that in such circumstances the object producing the sensation is one and the same, the idea of unity in the object becomes irresistibly associated with the impression."

We have quoted the above from his article on "Light" in the *Encyclopædia Metropolitana*, to which we refer our readers, should they desire a philosophical dissertation on the subject.

Returning to our "reflections," we here state a law of light which has many interesting applications; it is this. A ray of light falling on a reflector is reflected at the same angle as that of incidence.

Experiment 23.—Thus, place a reflector, such as a common looking-glass, so that the sun's rays shall fall upon it; or sti better, the light of a candle, as in fig. 8.

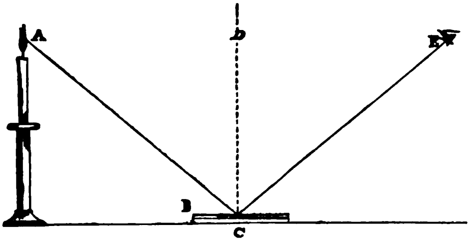


Fig. 8.

Here we have the ray of the candle, A, striking the reflecto B, at C, and we will suppose that D C is an imaginary straigh line touching the point C, where the ray falls on the glass. T see the ray at C, the eye must be placed anywhere in a straigh line, E C. Now, if you measure angle A C D with the angle E C D you will find them to contain each the same number of degree The angle A C D is called the angle of incidence, and the angl E C D, the angle of reflection; and as they are always equal you may easily, by arraying a number of mirrors, take the ligh from a parlour to any part of the house.

Experiment 24.—To illustrate this, place outside of th parlour-window a looking-glass, so that it shall form an angl of 45° with the window. You may now sit with your back say to the south end of the street, supposing you have place your glass facing south-east; and by looking at the face of th mirror, your eye being directed to the north-west, you will se everything passing in the street southwards, with the mos perfect ease.

We have been particular in our description, so that yo might not misunderstand us. You may tell your young friend that you know how to see behind you, and so amuse yourselves This plan is used in some of our seaside resorts, where th apartment has no direct view of the sea. Thus, supposing tha you reside in a long street, whose end is seaward, you ma arrange a looking-glass so as to always have a sea-view b reflection.

This arrangement has been proposed for use in mines wher it would be unsafe to have candles. A similar plan is employe in large towns for the purpose of lighting back warehouses an cellars.

Reflectors of a curved form, made of either silvered glass or polished metal, are used for the purpose of both collecting and diffusing rays of light.

The simplest one we can name to you is a watch-glass, whose *back* is coated with mercury. On presenting such a reflector to the rays of a candle, you will find that the light is brought to a focus just as if you had employed a lens.

A tin-basin, a meat-screen, the reflectors used in light-houses, in the lamps of railway-signals, and in common carriage-lamps, are all instances of what are called concave, or hollow reflectors. The outside of a polished teapot, a silvered glass globe, and such other reflectors, are called convex; and whilst the former condense the light to a focal point, these diverge or spread the rays in all directions.

EXPERIMENT 25.—You may easily make a concave reflector, by getting the coppersmith to hammer a piece of copper of a circular shape into the shape of a watch-glass. When complete, it should be twelve inches in diameter; and by then cleaning the inside surface with nitric acid and a little emery powder, you may get a rough polish. This must now be improved by rubbing it with fine rotten-stone and sweet oil, until it reflects the features of the face completely. It should now be electro-plated (see "Electro-Chemistry"), and afterwards polished by rubbing it with Tripoli powder, spirits of wine, and cotton wool, commencing with the centre of the inside until you arrive at the edge. Two of these should be made, and with them you may try a vast variety of interesting experiments.

You can have blown at the glass-maker's two concave glasses, and silver their *outside* with mercury, as described in our Chemical Experiments. These may be purchased ready-made, at most looking-glass makers'.

We have given the former method, as you may succeed in it with a little patience and hard work. For very elementary experiments, two common gas-reflectors will do; these may be obtained either at the tinsmiths', or of the gas-fitter.

The *convex* mirrors are made by either polishing the *outside* of the metal, or the *insides* of the glass-reflectors. The use of each we shall describe in our future experiments.

EXPERIMENT 26.—Ascertain the focal point (see Experiment 19) of one of these concave reflectors, by holding it so that the light of a candle may fall on it, and at the same time letting the smoke of some smouldering brown paper rise in front. You will detect the focal point by noticing the place where the rays from the mirrors cross each other, as illustrated in fig. 9.

You will thus observe that a reflector of this form acts on the rays of light as does a lens. In the lens, however, the rays pass *through*; but with the reflector the rays are *cast off* its surface.

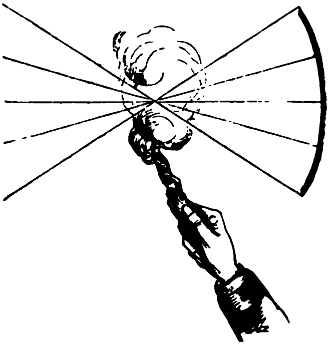


Fig. 9.

Experiment 27.—Stand before one of these reflectors; you will find a highly-magnified image of the face thrown from it, and you will thus learn that a concave reflector can magnify the image cast on its surface.

For this reason, these reflectors are used in constructing what are termed reflecting telescopes, of which we shall speak hereafter.

Experiment 28.—Burn a little blue fire on an elevated place, say on the top of the house, and hold the reflector behind it. The rays will be sent to a great distance.

Reflectors of this kind are employed in lighthouses, and the light from a lamp may thus be seen at a great distance at sea. Revolving lights are produced by causing the reflector to revolve round the lamp. The light is thus sometimes cut off, and by means of clock-work is made to successively illuminate the whole horizon.

Experiment 29.—Place your two concave mirrors face to face at a few feet distant from each other, and in the focus of one place a red-hot ball of iron, or a little chlorate of potass and sugar. In the focus of the other place a small piece of phosphorus. You will find that the heat and light produced from the ball, or on setting fire to the chlorate of potass, &c., will be reflected from one mirror to the other, and that the heat will be sufficient to inflame the phosphorus. We here have an instance of the reflection of light and heat at the same time.

ARTIFICIAL LIGHT.

Having in our previous pages attempted to give you some idea of the nature and laws of light, we now proceed to examine its different applications, commencing with artificial light.

In our own day, the chief means of obtaining light is that of combustion. We have already drawn your attention to this in our Chemical section, under the heads of "Oxygen," "Hydrogen," and "Carbonic Acid." And with respect to candles and lamps, we may just observe that the light obtained by their burning is just in proportion to the speed with which the charcoal of the fuel is allowed to combine with the oxygen of the air. We thus found that, if a candle was immersed in a jar of oxygen, the light was greatly increased, and that, by admitting oxygen in the centre of a gas or oil-flame, we obtained a brilliant light, called the Bude-light.

There are two lights which are not produced solely by combustion; namely, the lime light and the electric light. The electric light we have already mentioned in our Voltaic Experiments. With respect to the lime light, we suggested a modification of it, under the name of the oxy-calcium light, but the following description of the apparatus required for its production may be interesting, more especially as the New Westminster Bridge has been lately lit with it.

Two bags or gas-holders are filled respectively with oxygen and hydrogen gases, and a pipe leading from each is connected with an oxy-hydrogen blowpipe (fig. 10).

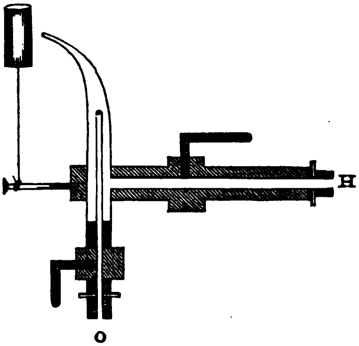


Fig. 10.

The engraving illustrates the usual form of blowpipe. In the jet a small pipe runs from the stopcock marked O, and by means of this the oxygen does not mix with the hydrogen, which is supplied through H, until near the end of the jet. This arrangement prevents any danger of explosion, by keeping the gases separate. On the left is a small cylinder of lime, against which the burning gases impinge. To use this apparatus, the hydrogen is first allowed to pass through its stopcock, H, and is ignited at the end of the jet, its flame playing on the lime cylinder until that is quite dried. The stopcock of the oxygen pipe, O, is now opened very gradually, and the gas passes up the narrow tube, mixing with the hydrogen near the end of the jet.

As soon as the two gases ignite together, a brilliant light is produced from the lime cylinder, owing to its particles being volatilized. That such is the cause may easily be shown by removing the lime for a moment, when, although the flame is of enormous heating power, it affords little or no light.

This has been called the oxy-hydrogen, the lime, and also the Drummond light, from the fact that a gentleman of that name employed it first for illuminating purposes. A company has been lately formed for the purpose of extending its employment.

The objection to both this and the electric light is, that the shadows produced are so deep. In positions where a single light of great power is required, they, however, are certainly of great value.

We must here also notice a new light which has lately been proposed by Mr. Holmes, and is now in use at the South Foreland Lighthouse.

It is obtained by the revolution of magnets in front of pieces of soft iron, surrounded with copper wire, by which electricity is produced and employed to ignite charcoal points, just as we described under the head of Voltaic Electricity. Its value, like the electric and lime lights, depends on its intensity. In fact, either of these lights is invaluable for the purpose of lighthouse illumination, because the light has the power, to a great extent, of penetrating vapour, fogs, &c. In one instance the lime light was seen at a station nearly one hundred miles from the place of its exhibition, of course reflectors being used to condense and direct the rays.

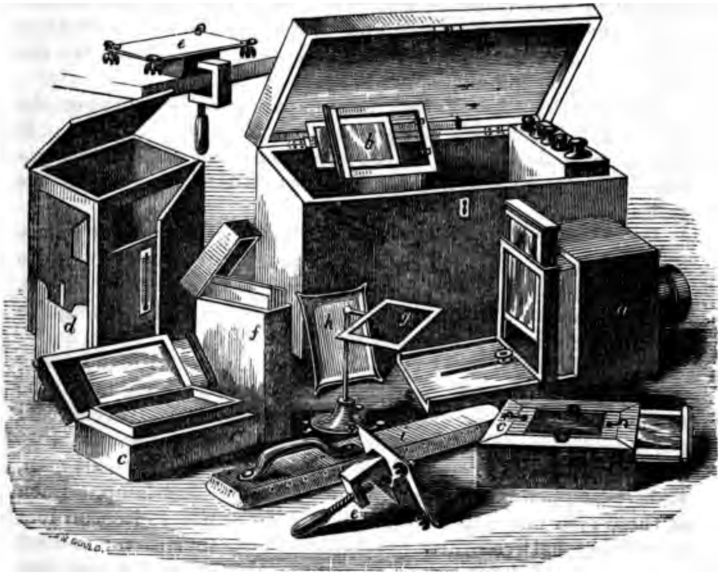
As one of the most interesting applications of light, we shall introduce remarks and experiments illustrating the Safety, or Davy Lamp.

EXPERIMENT 30.—*The Davy, or Safety Lamp.*—To understand the principle on which Davy's lamp is constructed, place a piece of wire gauze over a gas-jet, and light the gas *underneath* the gauze. You will find that the flame will only burn beneath, and will not pass through the gauze. You can try the same with the common spirit-lamp.

EXPERIMENT 31.—Repeat this experiment by opening the stopcock and allowing the gas to pass *through* the gauze. If you now apply a light to the top, you will find that the gas burns on the surface, but does not ignite that underneath the gauze.

EXPERIMENT 32.—This is owing to the metal of the gauze conducting away the heat of the flame. You may prove this by placing a coil of copper wire round the flame of a candle, when, owing to its conducting power, the wire will extinguish the light, although it does not touch the wick.

To Sir Humphrey Davy is accorded the merit of applying these principles to the construction of a lamp which might be safely used by miners in places wherein a large quantity of coal gas is escaping. We, however, must not omit to mention that a strong claim has been made in favour of the late eminent man, Robert Stephenson, as the inventor of the safety lamp. Each of these men have, however, sufficient fame not to lose an iota by sharing between them the honour of the invention; and we would here point out to our young friends two noble examples of men who rose to the greatest eminence purely by their own exertions and abilities.



PHOTOGRAPHY.

We shall now bring before you a variety of interesting experiments, illustrating the different means employed for obtaining pictures by the agency of light; and by a little attention and care, you may soon attain to a sufficient knowledge of the art as will enable you to copy a great variety of objects.

By referring to our remarks in the Chemical section on Silver, you will find that some of the salts of that metal change on being exposed to the action of light. But these are not the only substances which may be so changed; solutions of other salts produce the same result, and give pictures varying in colour according to the substance employed.

We will first suggest some experiments which will introduce you to the elements of photography, and shall afterwards give full instructions as to the different means employed for giving the best results in obtaining pictures on glass, &c.

Experiment 33.—Place a piece of glazed note-paper on a *solution of* common salt in water, and let it remain for some little time, so as to make it imbibe the salt in its pores. This is best done by placing the end of the paper next the finger, on the surface of the liquid, and drawing it until the whole of the paper is wetted on one side; then leave it to soak for a short time. The object of this is to prevent air-bubbles settling on the surface, and so marring the picture.

When properly moistened, hang the paper to dry, first marking the salted side with a pencil, so as to distinguish it. When quite dry, place the salted side, face downwards, in a solution of nitrate of silver, of the strength of fifty grains of the salt to an ounce of distilled water. The paper may be left on this for ten minutes, after which it must be hung up to dry in a dark place. This part of the process must be done by candle-light, because the salt of silver thus placed on the paper surface soon changes by the action of light.

Having prepared a few sheets, they may be kept in a portfolio ready for use, but of course out of daylight.

Experiment 34.—Expose a piece of this paper to the action of daylight, covering a portion of it by any opaque substance. You will find that the exposed part will soon turn black, the hidden part keeping white.

Experiment 35.—Place a piece of black net, lace, or a leaf, on a piece of this paper, and then expose to the sun for twenty minutes. Wherever the daylight has penetrated, a black mark will be produced. The net preventing the light from passing, of course will also prevent it from changing the colour of the

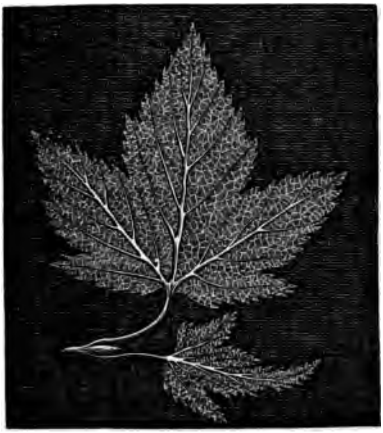


Fig. 11.

paper. On removing the article from the paper, you will find a complete copy on its surface. This copy will be exact in all respects; even the finest fibre is thus copied. (See fig. 11.)

The article should be pressed on to the paper surface by having a piece of plate-glass resting on it. A child's transparent slate is a very convenient mode of arranging the paper, &c. A piece of window-glass is first placed in the frame instead of the ground-glass; on this the article to be copied; next the paper with its prepared face against the net; and lastly, the back of the frame is to be put into its place. On now turning the glass toward the sun, the process will at once commence.

EXPERIMENT 36.—A photograph thus taken is not permanent, because the white parts are still liable to change, and would soon become black by exposure to daylight. To prevent this, and to retain the picture, you must fix it; that is, you must remove the sensitive portion still on the paper. If the salt of silver were soluble, this might easily be done by soaking it in cold water. But chloride of silver is insoluble in that fluid, and we therefore use hypo-sulphite of soda. Dissolve some of this salt in water, and on removing the picture from the frame, immediately place it face downwards on the solution, and leave it thus for some time. The solution will soon dissolve off, the chloride of silver be left unchanged, and the paper should be then left for some time in cold water, to wash out any soluble matter. It may afterwards be dried and pasted on a piece of cardboard. It will not be subject to any further change after being thus "fixed."

We recommend our young friends to repeat this simple experiment several times, so as to get the knack of practising. Success in photography depends on regularity, neatness, and care; and the sooner these qualifications are acquired, the better. To impress the order in which the different operations are conducted, we repeat them.

1. Salt one side of the paper.
2. Mark the salted side.
3. Dry the paper.
4. Place the paper with its salted face downwards, on a solution of nitrate of silver for about ten minutes. Do this at night.
5. Dry the paper in the dark.
6. Keep it in a dark place.

To take a copy of lace, ferns, &c.

1. Place the paper so prepared with its silvered face to the object.

2. Place over this a piece of plate-glass, or use the transparent slate.

3. Now expose to daylight or the sun's rays, until the uncovered part is of a dark mulberry tint.

4. Take the frame into a dark room, remove the paper, and place it, face downwards, in a solution of hypo-sulphite of soda for some little time.

5. Wash abundantly in cold water, and dry. Your picture is now finished.

The repetition of this process several times having to a certain extent initiated you into the art and mystery of photography, we now proceed to show how you may obtain copies which shall present a copy of the object as it really appears. The one you have made is what is called a *negative;* that is, the dark parts of the object are represented in the photograph by light lines, and *vice versâ.*

EXPERIMENT 37.—To obtain a positive copy,—that is, one presenting the same appearance as your object,—place the negative picture, face downwards, on another piece of the prepared paper; in fact, just substituting the negative copy for the lace. Place the two papers in the frame as before directed. The light will pass through the white parts, and darken the paper beneath. The dark parts of the negative will prevent the passage of the light, and so leave the paper beneath entirely untouched. You will thus obtain what we call a positive picture, and have one presenting the same appearance as the object itself has. (See fig. 12.)

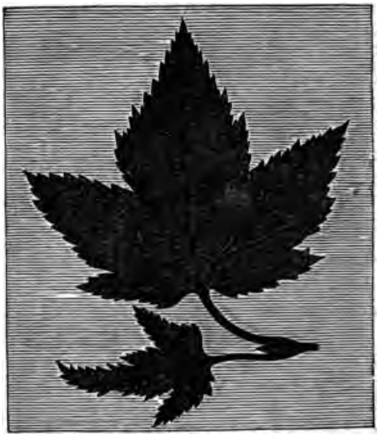


Fig. 12.

This must afterwards be removed and fixed, as we have before described. Our diagram illustrates the appearance of the *positive* picture when finished. Fig. 11 gives an illustration of a *negative* one.

We have hitherto only mentioned the preparation of a very simple kind of paper, because we did not wish to confuse by making our instructions too extensive. We, however, append recipes for the preparation of other papers, which give much better results, and which you can employ when your hand is somewhat accustomed to manipulate.

Paper ready salted and covered with albumen is sold by all photographic chemists. It only requires placing in the silver solution, by which it is made sensitive to the action of light. Of course it will require fixing when the picture has been taken.

PHOTOGRAPHIC PAPER RECIPES.

Salt Solution	Common Salt	1 ounce.
	Water	1 pint.
Silver Solution	Nitrate of Silver	50 grains.
	Distilled Water	1 ounce.

Another—

Salt Solution	Sal Ammoniac	30 grains.
	Water	1 ounce.
Silver Solution	Nitrate of Silver	100 grains.
	Water	1 ounce.

The proportions may be varied for other purposes. In every case use distilled water. We have previously given you in our section on Heat, an easy plan for making a still from a common kettle. If common water is used, its salt attacks the nitrate of silver, forming the chloride, and thus wasting it. To give you some idea of the necessity of using distilled water, and also of cleanliness in all your photographic attempts, we invite you to try the following experiment.

Experiment 38.—Presuming your hands are to all appearance quite clean, pour into a glass jar half a pint of distilled water, and also a little of the same into a clean wine-glass. Rinse your hands a few times in the water in the jar, and then add a few drops of a solution of nitrate of silver to it, and also to the water in the wine-glass. The latter will produce no change, but the water in the jar will have thrown down from it a white precipitate of chloride of silver, owing to the common salt present, which has been obtained from the perspiration of your hands.

We have often observed the annoyance of young photographers on finding black patches on their pictures; this is frequently owing to the fingers having been incautiously placed on the paper. Nothing is more essential than care in this respect, if you would ensure good pictures.

THE COLLODION PROCESS.

We shall not adopt the chronological order of discovery in arranging the processes of photography; but as by collodion we are enabled most readily to procure the best results in the art, we now proceed to describe its use.

Collodion is, as we have stated in our Chemical division, composed of gun-cotton dissolved in ether and spirits of wine. It is sold ready prepared at all the photographic chemists; and we advise you to purchase it thus, as you will not be likely to prepare it yourself, and there is no difficulty in getting any of the photographic materials by post from the large towns in any part of the kingdom. It is purchased under the name of "iodized collodion;" that is, collodion to which iodine is already added.

We need scarcely tell you that you will require a camera for taking likenesses and views. These are expensive, but the camera is the most important part of your apparatus. The simple one we shall describe under the head of Optical Instruments will not answer the purpose, and you will not be able to construct one with sufficient care as to ensure good results. We, therefore, shall give you illustrations of the camera and other apparatus required, remarking that all may be purchased in one lot, at a price varying from thirty shillings upwards to as many pounds.

THE PHOTOGRAPHIC CAMERA.

Our illustrations below will give you an idea of the usual form of cameras. In one the image is focussed by moving part of the framework of the camera (fig. 13). In fig. 14, the focussing is effected by means of rack-work fixed on the brass tube holding the lens. The latter is most convenient.

At the back of the camera a slide fits in, which is intended to

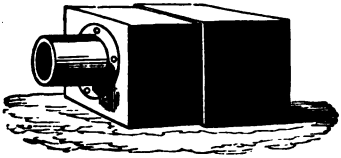


Fig. 13.

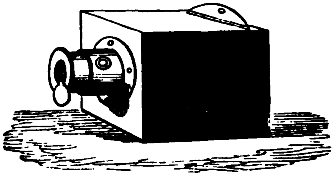


Fig. 14.

hold the glass plate on which the likeness is taken. A flap or shutter in front is placed so as to protect the plate from the light till after it is fixed in the camera. (See fig. 15.)

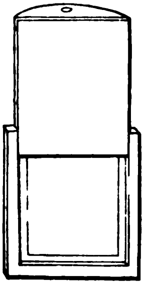


Fig. 15.

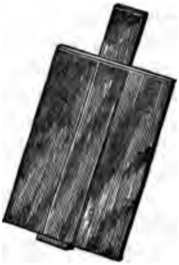


Fig. 16.

A dipping bath is used for holding the silver solution into which the plate, previously coated with collodion, is dipped, to render it sensitive to the action of light. The plate rests on a holder, as in fig. 16.

Both the bath and frame may be made of gutta-percha. The object of the frame is to prevent the wetting of the fingers in the silver solution.

THE WASHING DISH.

For this a common soup-plate will do very well. Or you may make a gutta-percha tray, ten inches square and two inches deep. You should have two of these, one for developing and the other for fixing.

We proceed now to each detail of the process, and shall suppose that you commence practising the art by taking a photograph of a plaster of Paris bust.

Having procured some glass plates, which are made and cut specially for photographic purposes, the first and essential process is to clean the plate. On the care you here exercise will much of the effect you will obtain be due. A dirty plate will be covered with spots, the collodion will not adhere, and, in fact, on scrupulous cleanliness all your results will depend.

To clean the Plate.—Hold the glass over the flame of a gas or spirit-lamp until it is moderately hot. By this you drive off a film of air which rests on every polished surface. We have never heard this recommended, but always practise it ourselves.

The plate is now to be left till cool, and must be cleaned and polished thus :—Pour on it a few drops of a mixture of ammonia and spirits of wine. Rub this well over the surface by means of a little cotton wool. Now wash well in distilled water, and let the plate drain, so as to remove the liquid. It must now be dried by means of a soft cloth, and then polished by a soft chamois leather, which has been previously cleansed by washing and drying. You must take care not to touch the face of the plate in any part with the fingers while polishing with the leather, which should be dry, warm, and free from dust. We generally lay the glass on one leather, and polish its surface with another one, and so prevent any chance of greasing by the hand.

To cover the Plate with Iodized Collodion.—Hold the plate with its cleaned surface upwards, and quite horizontally, as in fig. 17.

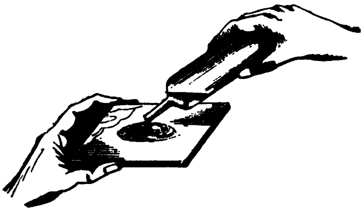


Fig. 17.

When the collodion is poured on to the centre of the plate, allow it gradually to spread in an even manner over every part to each edge, so that all may be equally covered. This requires dexterity, and therefore practice ; but you will eventually succeed in obtaining an even film by care and patience. Then drain the plate by holding one of its edges at the mouth of the bottle.

To make the Plate sensitive.—This process must be conducted in a room into which no light can possibly enter. We will call this the *dark room.* We have been accustomed only to employ the little light produced by burning a lamp fed with spirits of wine, to which salt has been added. The yellow flame will not hurt the plate.

The dipping-bath must have been previously prepared. It is to be filled with a solution containing, in the following proportions,—

Nitrate of silver	40 grains.
Distilled water	1 ounce.

Place the plate on the frame (see fig. 16), or if large enough, dip it, without the frame, into the solution, taking care not to allow the collodion film to touch any part of the vessel, lest it should be injured. Introduce it carefully and continuously; leave it for half a minute, then withdraw it, and return it again to the bath. It should be immersed about two minutes altogether. It must be drained from all superfluous solution.

The plate must now be placed in the dark frame of the camera (see fig. 15), and is then ready to be transferred to that instrument.

To take the Picture.—Having already placed your camera in position, and obtained a good view of the object on the ground-glass plate, remove this, bring your sensitive plate in its frame (see fig. 15), and covered with a black cloth, from the dark room, and place it in the frame whence you have removed the ground-glass, covering all with the cloth, to exclude light, of course, with the front of the plate to the lens. Put on the brass cap which fits at the end of the tube, and now cautiously slide up the black flap in front of the frame holding your glass plate. The cap may now be removed from the front of the lens. The light will proceed from the object, and its rays will instantly affect your plate.

The time for exposing will depend on the weather; and here we can give you no rule. In your experiments count thirty in a leisurely manner, which will be about equal to half a minute.

The cap must now be replaced. The flap in front of the glass plate let down, so as to cover the face of the plate again; and lifting up the frame so as to let the black cloth completely cover it, remove all into the dark room.

To develop the Image.—We shall presume that you desire to *obtain a "positive"* picture. As our directions have been given with that idea, we shall now direct you how to obtain one. The frame having been brought into the dark room, the glass plate must be carefully removed, and placed on a wine-glass, standing in one of the washing dishes we have already described.

On the collodion film the following solution is to be poured very gently, from a bottle or glass with a lip. It is made of the following ingredients :—

Proto-sulphate of iron	40 grains.
Nitric acid	2 drops.
Acetic acid	30 minims.
Alcohol	20 ,,
Distilled water	1 ounce.

We are indebted to Mr. Hennah for this recipe, and have always found it successful.

As the solution is poured on the plate, the image is gradually produced. The process must be stopped when the picture is sufficiently developed, and the next step is to fix it. By this you prevent the further action of light. Wash the plate abundantly in water before you attempt to fix the picture.

Immerse the plate in the other washing dish, which should be filled with either of the following solutions :—

Hypo-sulphite of soda	4 ounces.
Water	16 ,,

Or—

Cyanide of potassium	100 grains.
Water	16 ounces.

Of the two we much prefer the latter. After using either of these, the plate must be well washed, to free it from every trace of the salt. We generally allow water to run on it gently from a tap, and then immerse it in distilled water. The plate is then drained, and being held over the flame of a spirit-lamp, is to be gradually dried.

It must now be backed with a solution of asphalte in naphtha. This black varnish is sold by the chemists, but in extreme cases common Brunswick black may be used.

The picture being now complete, may be mounted and preserved for any length of time without danger of change.

NEGATIVE PICTURES.

These pictures are, of course, the reverse of the positives, and are employed for obtaining copies on paper. The process up to developing is the same as that for positives, except that the collodion film should be rather thicker, and the plate should be exposed for a longer time in the camera.

After bringing the frame into the dark room, place the glass on a wine-glass in a clean washing dish, and pour gently over it some of either of the following solutions :—

Proto-sulphate of iron	1 ounce.
Acetic acid	12 minims.
Distilled water	1 pint.

Or—

Pyro-gallic acid	5 grains.
Glacial acetic acid	40 minims.
Distilled water	10 ounces.

(This must be filtered before use.)

The plate must then be well washed, and may then be fixed as we mentioned for positives.

To preserve the collodion from injury, it should be coated with a very thin cover of copal varnish ; and it may, when dry, be used for the purpose of obtaining positive pictures on paper, for which we will give directions.

To obtain Positive Paper Copies from Negatives.—On a piece of sensitive paper, prepared as in Experiment 33, place the negative picture obtained as above, with its face downwards. The two should now be put into a copying frame, or in our child's slate substitute, and exposed to the action of daylight. By this you will obtain a positive copy, which must be fixed and dried. A negative will give you any number of positive copies, and thus you may distribute such to any extent amongst your friends. The albuminized paper is the best for this purpose.

In the preceding instructions we have given you what we know may be reckoned on as sure to prove successful, providing you observe all proper precautions. We may just add the following remarks, so as to impress certain essential points on the mind :—

1. Be sure your glass plate is perfectly clean before using it.

2. Let the collodion film be even in thickness in every part.

3. Dip the plate continuously into the silver solution. If you hesitate or stop as you dip it, a line will be formed across the plate, which will render it useless.

4. Take care that no light falls on the plate until you allow that which passes through the camera lens. The slightest exposure otherwise will spoil it.

5. Do not shake the camera as you introduce the dark slide. If you do, you will lose the focus, and get an indistinct picture.

6. Keep the black cloth over the top of the slide whilst the plate is in the camera, lest a little light should pass in at the top opening.

7. Develop your pictures *gradually*, and keep out all light from the room in which you do it, except that we have recommended. Some use a candle or low gas-flame, but these injure sensitive plates.

8. Wash carefully the plate before attempting to fix the picture; and after fixing, wash well in cold water, or the picture may be stained and so spoilt.

Do not choose sunshine on the objects you are photographing, because this makes the lights too white and the shadows too deep. A dull day gives often the best pictures. This is partly owing to a blue tint, or the prevalence of blue rays at such times. You may even observe this by looking at a distant landscape, which will always present a blue tinge just before rain.

THE DAGUERREOTYPE.

We shall not go into details of this process, because it is so rarely employed at the present time. We shall also omit any description of the Calotype and other modes of obtaining light-pictures; but before concluding this part of our subject, we must refer you, amongst many other valuable works, to those of Professor Hunt, viz. his "Manual of Photography," and of Messrs. Sparling and Martin on "The Photographic Art," either of which you may consult. From these books you may obtain every information, and we have to acknowledge that to the study of the former we are indebted for most valuable instruction and assistance in our own career in photography. Our desire has been to give you an insight into this interesting branch of applied science; and if you wish to pursue it in its various uses, we leave you in full possession of every information, by referring you to the works we have named.

PORTRAITS TAKEN BY ARTIFICIAL LIGHT.

We are not aware that any accounts have been published of the mode of taking likenesses at night. In the year 1856 we used, every evening during our lectures on photography at the Polytechnic Institution, Glasgow, to take a likeness by means of the electric light. The battery power was fifty cells of Grove's battery, each platina exposing an active surface of twenty-four square inches. The lamp employed was a modification of Duboscq's, and the time of exposure varied from thirty to fifty seconds. The great objection to such photographs is the bright nature of the white parts, and the intense shadow of the dark ones.

A gentleman of the name of Moule has lately patented a process wherein he employs what he terms the photogenic lamp. We have frequently employed the blue fire mentioned in our Chemical Experiments, and find the results softer than those obtained by the electric light. We believe that Mr. Moule uses a somewhat similar composition.

COLOURING PORTRAITS.

All attempts at obtaining the colours of objects, by direct photographic action, have hitherto entirely failed, although faint hopes are entertained that success eventually will accrue.

Photographs are now coloured by painting on their surface with various pigments applied by means of a fine camel-hair brush.

The success of these depends entirely on the delicacy of the taste and skill of the painter; and in many cases the absence of these qualifications is evidenced by the ludicrous daubs which "ornament" the show-boards with the cheaper sort of productions.

The application of oil-painting to photography has been, in many cases, highly successful, and some beautiful results are obtained. In these instances the photograph is merely used for the purpose of obtaining the outlines of the features, and the shade and expression of the face. The colours are painted over the photograph, and so give life and expression to the picture.

PRETCSH'S PROCESS OF PRINTING BY LIGHT AND ELECTRICITY.

We must not omit mentioning a process invented by a gentleman of the name of Pretcsh, of Vienna. Employing a glass plate, on which has been poured a mixture of glue, bichromate of potass, nitrate of silver, and iodide of potassium, he has been able to transfer engravings and photographs thereto by exposure to light. Those parts of the glue which have received the light become hardened, whilst the others beneath the dark part of the picture, remain soft. On moistening this, the soft lines immediately rise beyond the level of the plate, and produce exactly the same appearance as the plate would if it had been engraved. A copy of this is taken, and being black-leaded, it is covered with copper by means of the voltaic current. (See our section on Electro-Chemistry.)

From this another copy is taken, and thus a complete engraved plate is produced, from which any number up to 600 copies may be printed on paper. The only difficulty in the matter is the softness of the electro-deposit, which will not permit more impressions than those we have mentioned to be taken from one plate.

The inventor kindly showed us the entire process some years ago; and certainly it appears most beautiful in its results; and is an astonishing application of two forces—Light and Electricity—to the purpose of engraving without the assistance of human agency, so far as skill is concerned.

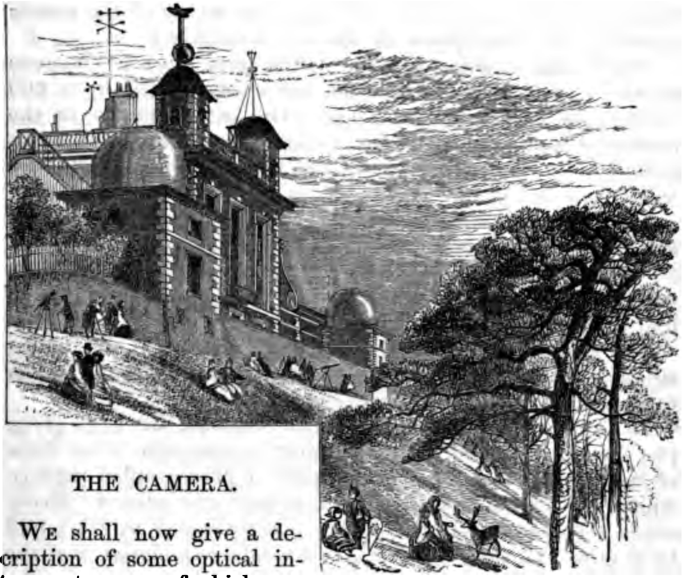
The engravings produced have rich soft tints; and whilst seeming to be the production of the engraver, have, if taken from photographs, all the fidelity of nature itself.

In the foregoing experiments and remarks, we have given you the bare elements of this wonderful application of the force of light. There is, however, no part of photographic practice which will not afford you much amusement and interest. Every object capable of casting a shadow may be copied by you; and to so great an extent has the art been lately employed, that the "likenesses" of the sun and moon are now often sold in the shops. Indeed, some of the most interesting appearances of the sun during the eclipse of July, 1860, were taken by these means.

The art of taking stereoscopic pictures is too difficult to be attempted by our young friends. We shall refer to the stereoscope under the head of Optical Instruments.

The head-piece to this section illustrates a variety of apparatus generally used by photographers.

OPTICAL INSTRUMENTS.



THE CAMERA.

We shall now give a description of some optical instruments, many of which you can construct yourself, and which will afford you a large variety of amusement. As one of the most simple of these, we commence with the camera.

Have made a box of tin or zinc, say ten inches long, six inches wide and four deep, with a lid at the top, extending, as in our diagram (fig. 18, A, B, C), and hinged so that the lid may shut down, or open, as required. A hole must be made at the other end, in the centre of the box, large enough to receive a lens, say an inch and a half in diameter.

The lens, a double-convex one, may be fastened by means of a little putty at D. The box must be blackened inside with a little glue and lamp-black. In the other end, under the lid, fix a piece of looking-glass, as wide as the box, and at such an angle as that it will throw the rays of light passing from the lens through, in a straight line, on to a piece of ground-glass, F, which is to receive the image, and on which you view it. The rays will be reflected from E to F.

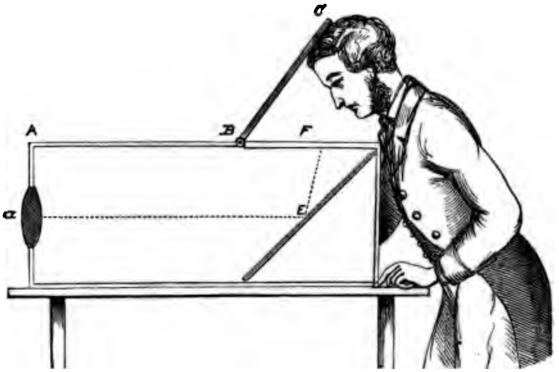


Fig. 18.

Experiment 39.—Place the camera at a parlour window, and on looking on F you will observe an exact image of every external object.

Experiment 40.—By means of a camera you may take the likeness of a friend, or a drawing of any object. For this purpose place a piece of thin paper over the glass, F, and trace the lines on it by means of a lead-pencil.

Another kind of camera may be easily constructed, which being placed on the top of a house will give a complete picture of all surrounding objects on a white screen or table, placed beneath it. To construct one of these, fix a lens, horizontally, in a tin tube, and outside of the tube attach a piece of good looking-glass, as in fig. 19.

The tube, lens, and glass may now be fixed, by means of a rod, to a table, and black cloth hung round so as to exclude all light, except that coming through the lens. If this arrangement is now fixed at the top of the house, or other elevated place, and a sheet of white paper placed on the table, the images of distant objects will appear on the paper; and you may thus enjoy the surrounding scenery, and sketch it on the sheet of paper. Fig. 19 will at once illustrate the construction of this instrument.

The lens and tube are made to turn round, or the looking-glass may be so arranged as to turn instead; and thus you may scan the whole horizon, and enjoy the view of the landscape, by this simple and easily-constructed camera.

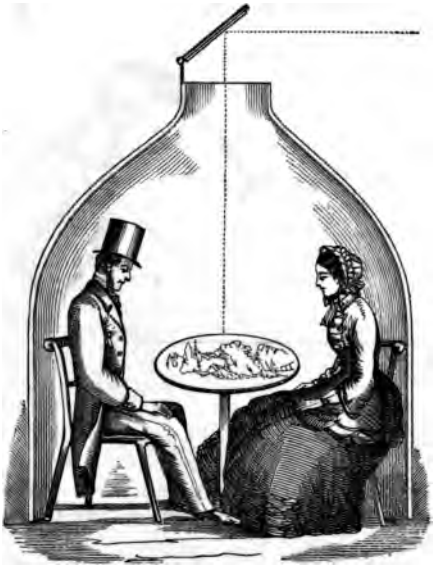


Fig. 19.

Photographers use a camera constructed on the same principle; but instead of receiving the image, as in fig. 18, they place the glass upright, in front of the lens; and the prepared plate is introduced in the place of the ground-glass, after focussing, and receives the image from the object you are about to take a photograph of. Arrangements are also made to focus the lens in front, so as to obtain a completely-defined picture. A full description of this class of camera is given under our section on Photography.

By aid of a camera, our young friends may obtain a vast amount of amusement; and to very young folks it affords an excellent means of learning to draw. The first one we have described is one of slight cost, say of not more than a couple of shillings altogether.

THE MAGIC LANTERN.

Magic lanterns are now sold at so low a price, that we shall *not give any* instruction as to making one, but rather give you such hints as may enable you to exhibit the pictures in a successful manner.

The parts of the lantern requiring most care are the lenses and the lamp. The lenses should be carefully taken out of their frames, and cleaned by rubbing them first with a little cotton wool, soaked in spirits of wine, and drying them by means of an old silk handkerchief. They should finally be polished with a soft chamois leather and replaced. Take care that the lenses are warmer than the air of the room in which you are about to exhibit, otherwise they will be covered with moisture, and entirely spoil the effect of the pictures. You can warm them by having the lamp lit some time before you show the pictures. Its heat will answer well for this purpose. The lamp should be carefully trimmed, so as to leave an even edge on the cotton wick; and always use the best sperm oil, as it gives the clearest flame in an oil-lamp. Be careful that the centre of your flame is level with the centre of your lenses, or, in other words, a straight line drawn from the centre of your lamp-flame should pass through the centre of both lenses.

Our young friends may apply the oxy-calcium light mentioned in our Chemical Experiments ("Oxygen"), instead of the oil-lamp. For this purpose the bottom of the lantern should be taken out, and the blow-pipe jet placed opposite a piece of lime, the flame of the spirit-lamp being between the two. The jet should be connected, by means of an india-rubber tube, with a bladder or bag filled with oxygen. The bladder being placed on the floor, should be pressed by a board on which there is a weight; on opening the stopcock, the oxygen will issue from it through the jet, and, forcing the flame of the spirit-lamp on the piece of lime, will produce a beautiful white light, far exceeding the effect of several oil-lamps.

The lime should be filed from the lump into the form of a cylinder, say one inch long and half an inch thick. A small hole is to be bored half-way through at one end, by means of which the lime can be hung on a wire in front of the jet. As the lime gets hard, and sometimes in holes, by the force of the flame, it should be turned now and then, so as to expose a fresh surface.

The application of this light to a magic lantern wonderfully increases the effect of the pictures. Mr. J. J. Griffin, of Bunhill-row, has favoured us with an engraving of one which he employs. It is a convenient form, and we therefore append a description of it.

Letter *a*, fig. 20, represents the spirit-holder; *b* is the wick-holder, in which there are three tubes for separate wicks; *c* is the tube which brings oxygen gas from the gas-bag, the supply of the gas being regulated by the stopcock on *c*; *d* is the jet by which the gas is directed into the flame of the spirit-lamp,

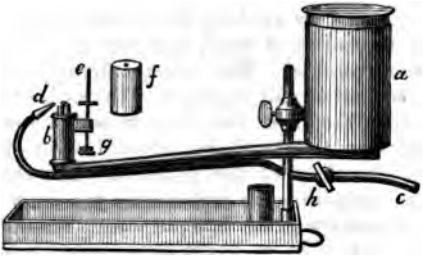


Fig. 20.

the wicks of which must be so arranged that the gas does not strike upon the cotton and produce a ragged flame, to which end the wicks must be carefully spread on the two sides; *e* is a wire for supporting the lime-cylinder, which is shown apart by *f*; and *g* is a milled head, for turning the cylinder, so as to present different sides of it to the action of the flame. The front end of the apparatus, represented by fig. 20, is put bodily into the lantern, through an opening made for that purpose in the back of the lantern. Letter *h*, fig. 20, shows a stand which serves to support the spirit-lamp, or an oil-lamp.

DISSOLVING VIEWS.

Two magic lanterns properly arranged can be made to afford what are called dissolving views. There is no difficulty whatever in managing this, provided your lanterns throw equal-sized pictures on the screen. The lanterns are to be placed side by side, and quite level. You must then place before them a piece of zinc of the shape represented at *d*, *d*, in fig. 21, so that each piece may alternately be in front of one lantern. Our illustration (fig. 21) will give you an idea of the whole arrangement.

Letter *a* represents the slide-holder; *b* is a slide partly inserted into the holder; *c* is part of the rack-work for adjusting the lens to the picture. The adjustment is regulated by the appearance of the picture on the screen. *d*, *d* is the *dissolving apparatus*; that is to say, the apparatus for making one picture gradually disappear while another gradually comes into view before the spectators. This change of pictures is managed thus: —The bar, *f*, attached to the screen, *d*, *e*, *d*, ascends and descends in a collar that is screwed to the front of the box on which the apparatus is mounted. It is provided with a rack, which is acted on by a pinion marked *g*. This pinion is turned by a handle. Supposing the pair of lanterns to be in action, and each lantern to contain a slide; one of these slides will give a picture upon the white screen, while the other is stopped by the upper limb of the screen, *d*. If then the screen, *d*, *e*, *d*, is gradually raised, by the turning of the handle, *h*, which causes the racked bar, *f*, to ascend, the acting slide will gradually become covered by the rising comb of one end of the dissolver, while the other will, in the same proportion, become uncovered by the

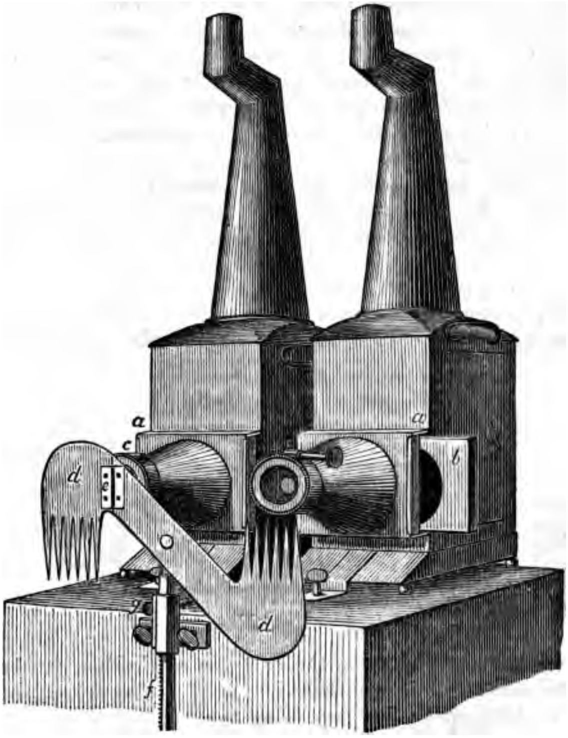


Fig. 21.

rising comb of the other end of the dissolver; so that, when the first picture is quite obscured, the second will be quite developed. In that manner the first picture is made to dissolve or gradually fade into the second picture. At *e*, in fig. 21, the dissolving-screen, *d*, *d*, has a hinge, the use of which is to admit of suddenly cutting off the action of the picture in the corresponding lantern. This action is required for the exhibition of *lightning* and other *sudden effects.* The change of slides in the lanterns is made when each nozzle is alternately obscured. The turning of the rack-work, by which the dissolving is effected, must be slow, regular, and noiseless.

We have here given the plan usually employed in the lanterns. We, however, will give another one which we used ourselves in the lanterns of the Glasgow Polytechnic, which is extremely simple in its construction, as you will see by fig. 22.

No. 1 is a piece of wood, with the holes, which are placed exactly opposite to the ends of the lantern lenses.

No. 2 is a slip of wood, made to slide at the back of No. 1. It is evident that only one of the holes, as cut in this, can be open at the same time with those in No. 1. Thus the right-hand ones are both open; but supposing that the slip is moved to the right hand, then the right-hand hole will be closed, and the left one opened. Thus by sliding No. 2 to and fro at the back of No. 1 the views are dissolved.

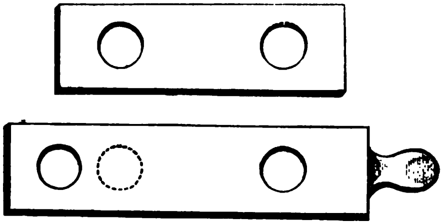


Fig. 22.

The screen on which the views are shown may be either transparent or opaque. A calico or linen sheet will do very well, and should be well and tightly stretched, so as to leave no creases on its surface. If the screen is opaque, both the spectators and the lanterns are *in front* of it. A nice effect is produced by having the lanterns *behind* the screen, which in that case should be wetted. By this arrangement the lanterns are hid from the spectators, and if placed in one room, with the screen hung between the folding-doors, say of two parlours, you may increase and decrease the size of the picture by moving the lanterns to and fro.

For home use two lanterns of three-inch diameter of the lens next the light will do very well. These lenses are called the condensers. Those employed in the Polytechnic, Regent-street, are nine and a half inches; but those we had in Glasgow were of enormous size, being lenses each twenty-eight inches in diameter, and having been blown hollow, were filled with distilled water.

We should recommend you not to *purchase*, but to *borrow* the slides; by so doing, you may always (if resident near a large town) secure a variety, and all the opticians are glad to lend them at a small charge, for the evening's use.

THE OXY-HYDROGEN MICROSCOPE, AND HOW TO MAKE ONE FROM A MAGIC LANTERN.

This instrument is, in every respect, similar to the magic lantern, except that its magnifying power is very much greater.

We had purposed to give you directions for applying a magic lantern, lit with the oxy-calcium light, as a microscope; but we fear that the details would be such as to require more optical knowledge than perhaps you may possess.

You may, however, easily get an optician to fit in front of the lenses of the magic lantern one or two powers, and so make a tolerably efficient microscope. We once converted one in this way ourselves, and the whole cost did not exceed five shillings. The only thing required is to lengthen the tube, and at the further end, near the lenses, to make a slit, in which the objects are to be placed. You will thus perceive that the arrangement differs very little from that of the magic lantern. Great care must be taken that all the lenses' centres are in one straight line. We knew a friend who expended £30 over a microscope, in attempting to remedy some imaginary defect. On simple inspection, we discovered that all that was required was just bending a piece of brass straight, which had, for want of this, thrown a lens out of the line of centres. The lenses should be kept perfectly clean; and if at all dirty at any time, they should be cleansed, as those of the magic lantern, by the plan we have already described.

Until you have a microscope of this class you may show the following objects, considerably magnified by the lantern alone:—

Make a glass trough, just big enough to fit in the slit wherein you put the slides or pictures. This may be done by making a frame of wood, half of an inch thick and three inches high, having two sides, as seen in fig. 23.

Now cement on each side of it a piece of window-glass, by covering each side of the frame with melted gutta-percha or india-rubber, and pressing firmly the glass previously warmed; leave this till quite cold. It is used for holding water in which insects may swim. Having filled it with water, put in some small water-insects, such as water-fleas, beetles, &c., and place it in the slide-rest of the lantern instead of a view. The insects will be largely magnified, and you and your friends will be highly amused at seeing their image on the screen. They will be fighting, biting, and eating each other, and racing through the water at great speed.

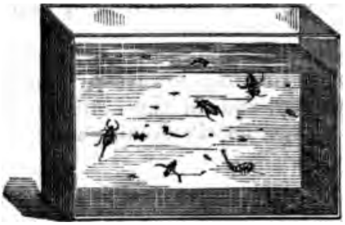


Fig. 23.

In such a trough as this you may exhibit, either in the microscope or magic lantern, all kinds of water-insects, weeds, &c.; and we shall give you a list of such as you may easily find in ponds by making and using a net of the form represented in fig. 24.

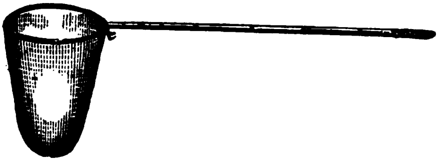


Fig. 24.

It is simply made of a ring of wire fastened to a handle, on which a piece of muslin is tied, so as to hang like a bag.

In searching for water-insects you must dredge the pond at its edges, and, having a basin by you, turn the contents of your net into it. On arriving home, pick out and keep in separate clean glass bottles the insects of each kind. We have often, in the course of an hour, gathered as many as a dozen different kinds. Change the water in your bottles every morning, and cast out any dead insects. By so doing, you may always keep a supply alive by you. In most ponds you will find, at different times of the year, some of the following insects :—

Water beetles.

Water fleas. (These are excellent objects.)

Water lice.

Worms in the mud.

Larvæ of the dragon-fly Two of these placed together in the trough will generally start a fierce battle, ending in the destruction of one, and sometimes of both.

The decomposition of water is a pretty object. A small piece of silver is put in the trough (see fig. 23), which is then filled with sulphuric acid, diluted with water. On touching the silver with a piece of amalgamated zinc, bubbles of hydrogen gas are given off.

Other objects should be placed between two pieces of window-glass, whose edges are pasted over with paper, to keep out the dust. Be careful to pick the glass quite free from wavy marks, as these would otherwise appear on the screen, and mar the effect. Fig. 25 will show you how to mount the object.

In this illustration we have two pieces of window-glass pasted together by paper edges, with the object enclosed between the glasses.

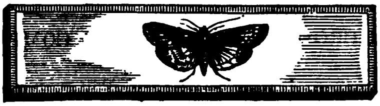


Fig. 25.

Living insects may be instantly killed by putting them into a jar of carbonic acid gas, already referred to in our Chemical section (see Experiment 42). This gives them no pain, and at the same time leaves them in the best state for mounting.

We suggest the following as interesting objects, most of which may be mounted as above :—

Butterflies of any kind.

Flies.

The wings of flies.

The legs of flies.

The eye of a fly.

The dragon-fly.

Feathers.

The down of feathers.

Beetles.

Mites in cheese.

Thin leaves of a tree, especially the currant and poplar.

Fern leaves. (These are very pretty objects).

Iron filings, left loose in the glass, to which a magnet is now and then brought. This will show the magnetic curves.

Crystallization of salts. A clean piece of glass is placed in the slide, on which a drop of a hot solution of common salt, or Epsom salts, is placed. As the moisture evaporates, the salt crystallizes, producing a very pretty effect.

Hair, of various animals.

Down from the wing of the moth.

Fishes' scales.

Spiders, and their webs.

The sting of a bee.

Sections of wood, showing its pores and rings.

String, cotton, linen, silk, &c.

We need not go further with our list. Every object in nature will afford you at once amusement and instruction of the most interesting kind.

THE MICROSCOPE, SINGLE AND COMPOUND.

We have mentioned how readily you may construct a simple microscope, by means of a drop of water and a piece of window-glass. (See fig. 4.) We shall now go more fully into a description of various arrangements by which you may be enabled to study some of the most interesting facts ot both animal and vegetable productions.

The microscope derives its name from two Greek words, and signifies "small," "see-er." In fact, its powers enable us to investigate the use and construction of objects far too small to be seen by the unassisted eye, and introduce us to a field of wonder only equalled by that which the telescope enables us to perceive in the heavens.

A common lens, or magnifying-glass, is, in every respect, a microscope, and for examining many objects will be found very *useful*. A thermometer-bulb, filled with water, can also be used for the same purpose; but a still better instrument, and one which will answer many purposes, is the Stanhope lens.

This is made of a lens which is ground doubly convex; it is generally about half an inch deep and wide, and mounted in a brass or silver frame. One of these is represented in fig. 26. They may be purchased at from half-a-crown upwards, and you may examine by them the animalculæ in water, mites in cheese, and a vast variety of minute objects. We strongly recommend our young friends to procure one of these little instruments. One can be carried in the waistcoat-pocket; and your country walks may be made to afford you a vast amount of valuable information, if you continually examine the objects you are passing.

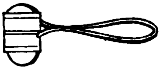


Fig. 26.

We have known some of our young friends who have delighted to spend a day in one field; and who have arrived home at night with a rich store of microscopic curiosities, whilst some of their companions have been, during the same time, wandering to and fro; and, at the end of their day's pleasure, returned tired and spiritless, simply because they have found nothing during their excursion which has excited their interest, having never sought for it.

Fig. 27 illustrates an instrument called the Coddinton lens. It also forms a good microscope.

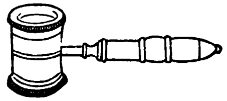


Fig. 27.

Having mentioned single microscopes, we now proceed to describe those of a more complex form; and although we cannot hope that you will be able to construct one, we shall advise you as to the purchase of one, so that you may have pleasure and success in its use.

COMPOUND MICROSCOPES.

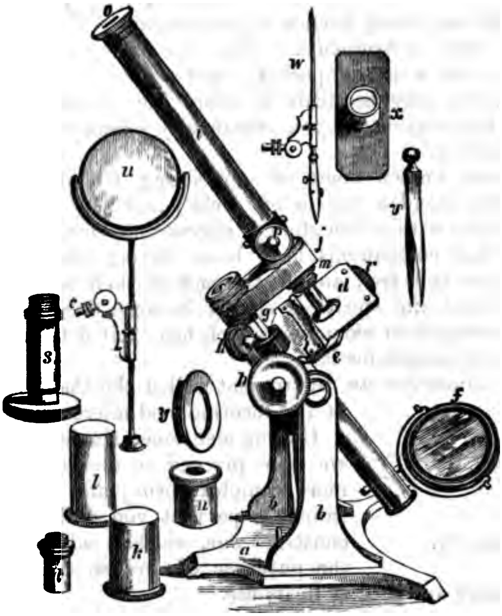
Microscopes are called compound when they contain two or more lenses, and, perhaps, there is scarcely any philosophical instrument on which the skill of the optician has been exercised more than in the construction of these instruments.

One of the greatest improvements has been the introduction of what are termed achromatic lenses,—that is, glasses which do not give coloured fringes at the edges of the objects viewed through them. Our young friends, should they purchase a compound microscope, must take care to procure an achromatic one.

To make the construction and use of these fully understood, we annex a diagram of one of the best form.

A very good one may be obtained for about three guineas; but by attending the sales of philosophical instruments, you may

Fig. 28.



In fig. 28 we have an illustration of the different parts of an excellent compound microscope, wherein

a is its stand.

b b, two supporters on which the microscope rests.

c, a peg fitting into the frame. It holds a lens, *u*, which is used to cast light on opaque objects.

d e, the frame on which the object is placed.

f, a mirror which throws light through transparent objects.

g, a rack-work for raising and lowering the tube, *l*.

h h, two thumbscrews for adjusting the focus.

i, a branch on which the tube, *l*, is fixed.

l, the brass tube holding the lenses.

The rest of our illustration need not be described, being powers, &c., which are added to the microscope for various purposes, and the use of *which our young* friends can only understand by practice.

sometimes have a chance of buying one cheaply. We advise that you take advantage of the experience of an optician, or otherwise you may be sadly disappointed in your purchase.

As most of our young friends will not be able to purchase an instrument of the size and quality of the one we have described, we annex an illustration of a simple one, which may be purchased for from ten shillings to a pound.

Fig. 29 represents one of these. Its principal parts are *a*, the magnifying lens; *e*, the frame on which the objects are supported; *h*, a mirror, casting light through transparent objects. The other parts in our figure consist in lenses of different magnifying powers, which are fixed in the holder, *d*; and forceps, &c., for holding the objects to be examined. If you are examining an opaque object, you can easily throw light upon it by holding a double-convex lens or burning-glass, so that its focal rays shall be cast on your object.

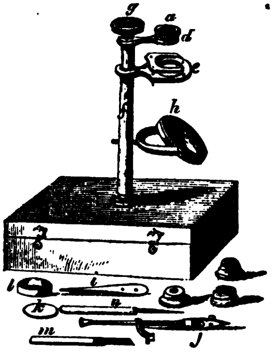


Fig. 29.

We have thus endeavoured to give you an idea of the construction and uses of the leading kinds of microscopes. No one need be without one, for the simple one we described at page 195, made of a piece of window-glass and a drop of water, will do. The Stanhope lens, which is cheap, is also excellent; and whichever kind you employ, you will find that a most interesting field of study and amusement is thereby opened out to you. We shall now attempt to assist you in getting objects for your microscopic studies.

OBJECTS FOR THE MICROSCOPE.

You will require a net by means of which you may catch insects without the danger of spoiling their wings. The one we described at page 226 will do. Let the net form a bag of about eighteen inches deep from the ring. By just shaking the branches of the trees as you pass, and holding the net, sweeping it occasionally, so as to receive the insects which fly out, you may soon obtain a good stock for the microscope.

Should you wish for insects only, the best time to seek for them is in the evening, just about dusk. Some even go out at night with a lantern, and blinding the insects by the light, catch a large number. This plan is best for butterflies, moths, and others of this class.

Caterpillars are chiefly found on the bark, and underneath the leaves of trees. They are excellent objects for small microscopes. The hair, the colours, the feet, and the eyes are very interesting.

In the ditches of a field you will find a vast variety of worms of all sizes and appearances; and in the stagnant water you may discover scores of animalcules of every conceivable shape. Many of these are the larvæ of flies, &c.

Gnats and other insects are mostly found buzzing near the hedges and underneath the branches of trees. Their wings are very small, and present a great number of different colours.

The dragon-fly's wings, body, and eyes are very excellent objects. These insects may be found flying over ponds and near rivers.

Beetles abound in most of our fields, and will be found amongst the grass. Their legs are well worthy of notice.

You will find a large number of green insects on the leaves of rose-trees. The garden and hedge will also afford you the bee and wasp, whose sting and wings will prove interesting.

Amongst vegetable objects we may hint at the following:—The flower and seeds of the thistle and dandelion; the down of many leaves; the structure of different sorts of grasses and weeds, ferns, sections of wood, &c.; leaves of flowers, their petals, &c.; the down of flowers; roots of plants and their fibres, or "suckers;" water-plants; chick-weed and its root; mosses, fungi, or vegetable productions of the mushroom kind; and other such matters.

The skin of the human body, its perspiratory pores, the hair, *&c., also* form excellent microscopic objects; in fact, were we to attempt to enumerate all such matters, we should have to make a list of everything on the face of the earth, an attempt which we most respectfully decline to perform.

THE TELESCOPE.

The telescope derives its name from two Greek words, signifying "to see at a distance." It is almost impossible for you to construct one sufficiently accurate for viewing landscapes, &c.; but we shall show you how to make one at a little cost, which will enable you to view through it some most interesting astronomical facts,—such as the spots in the sun, the moon's mountains, Jupiter's satellites and belts, Saturn's ring, &c. We are indebted to Dr. Dick for our description, and transfer his instructions from an interesting work of his, entitled "The Telescope and Microscope."

To construct a Simple Astronomical Telescope.—"A telescope of this kind may be easily constructed, and at a small expense. Procure a double-convex lens, about thirty-six inches' focal distance; place it at the end of a tube, as at A, B. At thirty-seven inches' distance from this glass fix another, C, D, whose focal distance is one inch. This glass must be fixed in a separate short tube, E, F, which should be made to slide backwards and forwards in the large tube, for the purpose of adjusting the focus of the telescope to the eye.

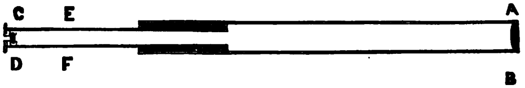


Fig. 30.

"In constructing such a telescope, the following particulars require to be attended to:—The aperture or opening which lets in the light at the object-glass, A, B, should not exceed one inch in diameter, otherwise the image of the object will be somewhat confused. There should be a hole (or stop) in the focus of the eye-glass, C, D, rather less in diameter than the breadth of the glass, for the purpose of excluding the extraneous rays."

A telescope constructed as above will magnify thirty-six times; and we must explain to our young friends that by object-glass, we mean the lens placed at A, B; and the eye-glass is that through which we look—that is, the one at C, D. The cost of a telescope of this sort will be about five shillings; the tube may be made of tin or zinc, blackened inside. The use of the metal stops at the ends is to give greater clearness to the image. They are made by fixing in front of each lens a piece of metal with a hole in its centre; which, to correspond with our telescope, should be one inch in diameter for the large end, and half an inch for the narrow or "eye-piece" end.

Take care that the lenses are fixed so that their centres shall be in one straight line. This telescope shows all objects inverted, which is, however, of no consequence in astronomical uses.

To relieve the tediousness of our description, we shall relate an anecdote which we met with in Scotland, which shows that telescopes may have various uses. A Highlander, after looking through a telescope at the moon, and astonished at what he saw, requested to be allowed to take another peep. Meanwhile the wag of an assistant had lowered the range of the instrument so as to bring in view a distant public-house. Our Highland friend on again looking through was astonished at seeing the sign-board of an inn, stating "Usher's Edinburgh ale sold here." He instantly exclaimed,—"Hey, mon, I didna ken they sold ales in the moon!"

THE COMMON TELESCOPE.

In this instrument four lenses are employed, and the image presented is an exact representation of the object to which the instrument is directed.

Achromatic telescopes are constructed which have many advantages over those we have described. The term achromatic means, "without colour," or, in other words, the lenses being made of two different kinds of glass, the effect of colour observed at the edges of objects viewed through ordinary lenses is entirely prevented, and the value of the instrument proportionally increased, especially when required for astronomical purposes.

REFLECTING TELESCOPES.

We must not omit to mention that telescopes are made with reflectors, although it will be beyond your power to construct one.

In these the image of the object is received by a concave speculum, as it is called, and viewed by means of an eye-glass. *The spectator* often has his back to that which he is viewing.

We shall describe the following for the purpose of giving you an idea of their construction.

The chief forms of the reflecting telescope are those of Gregory, Newton, and Herschel.

In that of Gregory the spectator looks *through* the telescope. In that of Newton the image is received by a reflector, and is viewed by an eye-glass on the *side* of the instrument. In Herschel's telescope the spectator looks *down* the tube at the speculum and with his back to the object.

Reflecting telescopes have been made of all sizes, the largest being that of Lord Rosse. This has a speculum six feet in diameter, with a tube fifty-six feet long, and is mounted between two walls of masonry.

Its magnifying power is such that a space of a few feet square could be observed distinctly on the face of the moon, and thus, if any large buildings existed in it, we should be able to detect their presence.

Our young friends should embrace an opportunity of visiting an observatory, and of thus getting an idea of the construction and use of these interesting instruments.

THE STEREOSCOPE.

Since the practice of photography has become so universal, opticians have constructed an instrument by means of which the flat surface of the photograph may present to the eye all that appearance of solidity which is observed in nature. We are indebted to Sir David Brewster and Professor Wheatstone for the optical instrument called the stereoscope, or as we may say, the "solid-viewer," which affords us this result.

As these are sold so cheaply we shall suppose that you have purchased one, and simply wish to know how it is that by looking through the two lenses, the picture seems to be solid, or rather gives a solid reflection to the eyes.

We refer you to our remarks on the eye, and the explanation afforded by Sir J. Herschel in reference to our seeing objects singly with two eyes, which we have quoted (see p. 197); but beyond this we may state that the photograph itself is taken in two views at the two different angles which the picture would present if viewed by each eye separately; being placed in the stereoscope, the rays passing from the two pictures reach the eyes through the lenses; and these presenting the pictures at what we may term the eye-angle, give them, to the eye of the spectator, the appearance of solidity.

In many cases some little haziness is observed when looking through the lenses. This is chiefly owing to the pictures not being placed so that the interval between them shall be exactly opposite a line drawn perpendicularly between the eyes. You must bear in mind that the position of the pictures and lenses must just correspond to what we have called the eye-angle. If, for instance, you cut an ordinary stereoscopic double picture in half, and place the halves out of this position in the stereoscope, you will observe two pictures instead of one.

You may construct a very cheap stereoscope by carefully following out the arrangement illustrated in fig. 31. This instrument was invented by Professor Wheatstone, and is called the reflecting stereoscope. One can be made by fixing a frame, *a a*, at each end of a board. The frames must have two pieces of wood at their sides, which are to be arranged so that a picture may be kept upright in them,—a slit in each frame will do. In the centre of the board two pieces of flat, best looking-glass, *b*, must be fixed at such an angle (45°) as that they shall reflect the image of the picture to the eyes when the nose is so placed as to be exactly opposite the centre line between them, *c*.

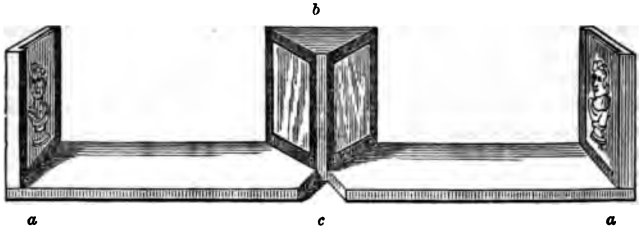


Fig. 31.

Our remarks on the "angle of incidence" will assist you in the arrangement. (See page 198.)

In using the stereoscope, place at each end a picture, and standing opposite to the centre line, *c*, between the glasses, *b*, the two images will be reflected to the eye, and will appear solid. Great care is required to keep the pictures upright, as if ever so little out of position the effect will be marred.

THE POLARISCOPE.

We now enter into what is a rather difficult, but most interesting subject, and we shall endeavour to make its principles as plain to be understood as possible ; affording you, at the same time, some most beautiful experiments.

In a previous part of this work we have spoken of magnetic poles (see Magnetism). We there told you that the north and south pole of a magnet had certain properties. Now, as in a needle we divided these two opposite states of magnetism one from the other, so are we about to get the poles of a ray of light by dividing it by means of double refraction.

This illustration of polarized light is not strictly scientific, but it will assist you very materially in understanding what we mean, and this is an object we always keep steadily in view.

EXPERIMENT 41.—By placing a piece of plate-glass on any writing, you only see the letters once reflected to the eye ; but by using a piece of Iceland spar you will find that two sets of reflections are sent to the eye—in fact, you see double, without at all breaking the rules of sobriety (see page 196).

Now, without mystifying you with a long tale of "undulations of the waves of light," &c. &c., which you would not understand, we simply tell you that if you bind together twenty or thirty pieces of clean window-glass, and place this bundle so that light shall fall on it at a certain angle, such light will be polarized; that is, the ray will be divided into two. One of these will be *reflected*, and the other will *pass through* the glass, or, as we say more scientifically, it will be *transmitted.*

EXPERIMENT 42.—*How to make a Polariscope.*—Obtain two tin tubes, each six inches long, and about two inches wide ; and let one be so much narrower than the other as just to allow it to slide and turn round inside of the other easily. At one end of each tube fix a piece of glass-plate, whose back has been blackened. These plates must each be fixed at an angle of 33° ; that is, about a third of a right angle. The tubes should be blackened by rubbing them on the inside with lamp-black mixed with a little glue.

EXPERIMENT 43.—If you now look on the face of either glass-plate, you will see the reflection from the other, if they are both in the same line. You will, however, find that on turning one round, in an entire circle, the light is twice lost and twice reflected ; and thus you have obtained the polarization of light.

EXPERIMENT 44.—The above is a very simple piece of apparatus, but we shall now describe one which is so very cheap, and at the same time so very effective, that we strongly advise you to purchase one, costing five shillings, as the most economical way of studying the beautiful effects of polarized light.

You may obtain others at the instrument-makers, but they are, generally speaking, very expensive. We accidentally discovered this at the South Kensington Museum, a day or two ago, and give you the advantage of our information on the subject in the words of the inventor.

DESCRIPTION OF BESTALL'S POLARIZING APPARATUS.

The apparatus for showing the above beautiful phenomena in glass, acids, salts, crystals, &c.—adapted for night or day—consists of a polarizing mirror, glass-stand for the proper angle, analysing tube, all of the most simple and cheap form, with all the properties of the most expensive apparatus. (See fig. 32.)

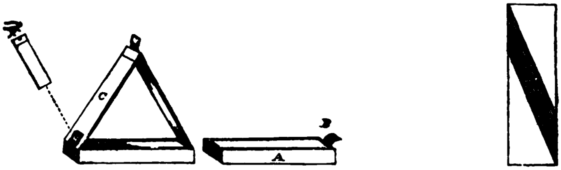


Fig. 32.

Directions for using Bestall's Polarizing Apparatus.—Hold the box, A, in one hand; pull the tongue, B, with the other, and that will give you the mirror and the glass for the proper angle. Place the black mirror in the box, A, with the reflected part upwards. Place the glass for giving the angle on the mirror, as in the drawing. Place the object on glass, C, and the ground glass to the light. Place it on a table by the window for day; for night a light to reflect about half-way up the ground-glass. Place the analysing-box to the eye, turn it gently round, and sit about two or three feet from the apparatus; look at the object, and you will get the phenomena of polarized light.

By turning the analysing-tube round, you will get the primary and complementary colour.

You can take the analysing-plates out of the tube when you wish to clean them, but be particular in placing them in the same position.

We have made a section of the box, in case you might forget the position, D.

Having thus described the instrument, we proceed to mention the effects you will observe in its use. Pieces of various crystals, such as nitre, plaster of Paris, &c., when looked through by the naked eye, simply appear transparent, like common glass. When, however, you view them by means of polarized light, they present the most splendid colours imaginable. A vast variety of substances may be examined; and, perhaps, there is no branch of science which presents such unlooked-for changes as you will thus be enabled to witness.

We have already explained what is meant by complementary colours. By means of the polariscope you obtain the primary and complementary colours in objects viewed by it. The instrument has been employed for a great variety of purposes, but our limits will not allow us to pursue the subject further.

We must not omit to give you the address of the inventor. It is 1, Victoria Cottages, Kennington Park, London. Objects ready cut and mounted may be purchased of any optical instrument-maker, and may be obtained in great variety.

We must now conclude our remarks on the interesting subject of Light. Under the head of Natural Magic, we shall describe other optical effects, and some instruments, such as the kaleidoscope, &c., which we have omitted here to mention.

In the previous pages we have, under the section of "Light," endeavoured to give you a general idea of some of the leading laws which have been discovered by men of science. We have not ventured to trouble you with any of the theories which have been advanced to explain the different effects which we have mentioned. We may, however, briefly state, that from the time of Sir Isaac Newton to the present day almost every philosopher engaged in optical researches has advanced special views in reference to the cause of Light. As far as the sun is concerned, some have imagined that an enormous combustion of some kind of matter is going on, and that from this we obtain solar light and heat. Others have thought that both these forces are produced by the undulations of waves of ether; that is, an extremely subtle substance of so refined a nature as not to be perceived by our senses. This idea has had many followers, because it explains so many effects without doing violence to sound scientific reasoning. To illustrate our meaning, we may just remind you of the effect produced by throwing a stone into a pond. A series of waves are formed, proceeding from a centre; and in like manner it has been supposed the waves or undulations of light pass to and reach the eye.

It has been suggested also, that light is a material substance of great tenuity; but careful calculations in reference to the speed of light give little countenance to this theory.

In our next section on Sound, we shall endeavour to explain more distinctly the effect of vibrations of the air; and if you substitute the idea of an ether instead of air, you will understand many of the laws of what has been called the undulatory theory, of which we have just spoken.

During the last few years some wonderful discoveries have been made; but still we are as far as ever from knowing what light is. Dr. Faraday and others have succeeded in magnetizing a ray of light; and various researches tend to sanction the idea that heat, light, electricity, and magnetism, are each produced by a modification of the same cause. But, after all, such is mere conjecture, and hitherto we have been unable to fathom the cause of an agent to which we owe most of the pleasures of our existence, and without whose presence nature itself would cease to be. We conclude by quoting perhaps the most expressive and awe-striking sentence in the Scriptures:—

"God said, Let there be light: and there was light."—Gen. i. 3.

EXPERIMENTS IN SOUND.

Next to the pleasures we derive from the sense of seeing, are those afforded us by the ear conveying sounds to the mind; and we now invite you to consider with us some interesting facts and experiments, by means of which we shall be able to introduce you to another branch of science called "Acoustics."

Every sound we hear is produced by the vibration of the sounding body, and is conveyed to the ear by the vibration of the particles of our atmosphere. Thus, if we strike a bell, the metal of the bell *vibrates*, and these vibrations continue from the bell until they reach the ear; and on their ceasing to be produced, the sound at once ceases also.

EXPERIMENT 1.—That vibration is produced when sound is given off, may be easily shown by the following arrangement. Obtain a large glass vessel with a thin edge, and half fill it with water; then draw the bow of a violin against its rim. The water inside the glass will be thrown into waves, which are produced by the vibration of the sides of the glass vessel.

EXPERIMENT 2.—These vibrations are both rapid and strong, as may be seen by hanging outside of a thin empty glass a small ball of wood, so as just to touch it. If you now draw the bow against the glass, you will find that the vibrations will be so powerful as to throw the ball one or two inches from the vessel, and it will continue to vibrate for some time, as in fig. 1.

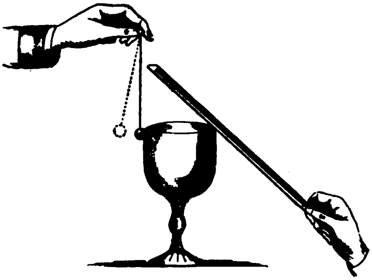


Fig. 1.

EXPERIMENT 3.—An ordinary tuning-fork may be taken as another instance of the production of sound by vibration. After striking it, you will observe that either leg vibrates as long as the sound is produced,—an effect illustrated in fig. 2.

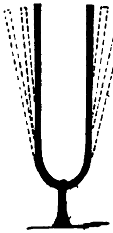


Fig. 2.

EXPERIMENT 4.—We need not multiply these illustrations. A penknife stuck into a piece of wood at its point, a string stretched tightly between two nails, a table-knife tilted on a plate,—such give instances of the same kind when they are put in motion.

Sounds differ in their nature and intensity according to the number of vibrations given out in each second of time. Thus, for producing the lowest bass we can hear, a vibration of 32 times per second is required, whilst 516 vibrations must take place to produce the sound of C treble. Just in proportion to the number of vibrations per second, are sounds either low or shrill; hence, as we proceed to strike each ascending note on the piano, *so does each* string vibrate oftener than its predecessor.

EXPERIMENT 5.—A very pretty musical instrument may be made by combining a number of glasses together. We will suppose that you arrange eight in the following manner, placing them on a hollow box. (See fig. 3.)

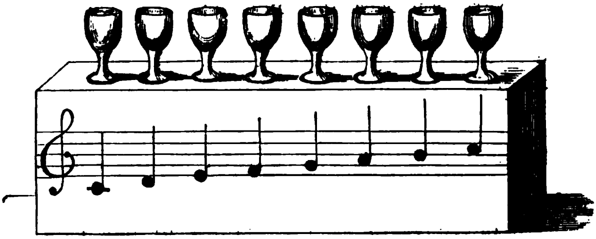


Fig. 3.

They should be chosen so that when vibrating they may give off eight successive sounds, corresponding with the eight notes of an octave. To ascertain their individual sound, wet a finger with a little lemon-juice, and rub it gently round the rim of each glass, and then arrange them accordingly. You may play any tune on them just as you would on the piano, by simply rubbing each rim; and you will thus obtain a simple, and yet at the same time a most pleasing musical instrument. On the outside you may paste a piece of paper, indicating the value of each note in the octave. In our illustration above we have chosen an octave ranging from C below to C on the third space, in the treble staff.

We once created much amusement at a large dinner-party in a friend's house. The finger-glasses were placed on the table, and for the sake of mischief, we rubbed the finger round the glass before us, and so produced a sharp tone. In a short time the whole of the company followed our example, and, much to the amusement of all present, our experiment converted us into a *musical* dinner-party. Finger-glasses answer this purpose most admirably, and in fact would be preferred to the tumbler had they feet, as they are generally made very thin.

The Harmonicon is constructed on similar principles. It consists of pieces of window-glass of different lengths, which on being struck by a cork hammer afford a very sweet set of notes.

Our experiments will thus have shown you that all musical sounds are produced by the vibration of the parts of the instrument; and this law holds good whether you apply the principle in constructing the organ, piano, bugle, flute, &c. &c. The fact is equally true as regards all other sounds. In the case of thunder, we have the vibration of the air; in concussions, &c., the vibration of the particles of the bodies, as the causes of the noise we hear.

We might interest you by stating facts respecting the construction of various musical instruments; but as we wish to be practical in our details, we now pass on to other matters, and leave you to consult larger works treating on the subjects we have omitted.

THE PROPAGATION OR CONDUCTION OF SOUND.

We hear sounds owing to the power which air and other media have of conveying the vibrations to our ears. The passage of sound to the ear may be very properly compared to the effect of a wave in water. The water scarcely leaves its place, although seeming to move very rapidly. You will often fancy, on looking at the water in a river, that it is rushing in one direction when it is really going in the contrary, the waves on its surface producing the erroneous impression.

Now, whenever sound is produced, waves of vibrations are sent from the sounding body on every side, just as you will observe circular waves are formed in a pond on a stone being cast into the water. The sounding body forms the centre of these waves, and, on the latter reaching the ear, we perceive the sound at once.

Sound travels through the air at a speed of about 1140 feet per second, but at different rates in other bodies, according to their densities.

You may easily calculate the distance of a vessel by observing the length of time which elapses between the appearance of the flash and the arrival of the report of a gun fired on board of her. Supposing, for instance, that five seconds have elapsed since the flash appeared: you need only to multiply 1140 by 5, which will give you 5700 as the number of feet the vessel is distant from you; and dividing this by 5280, the number of feet in a mile, you will have her distance at a little more than a mile—1 mile 140 yards.

The distance of a flash of lightning may easily be calculated by noting the number of seconds which elapse between perceiving its light and hearing the sound of the thunder. Multiply 1140, the number of feet per second which sound travels, by the number of seconds which have elapsed; and if you then divide the product by 5280, the number of feet in a mile, you will have the answer in miles and feet. *Example.*—How far is the flash of lightning off, supposing 12 seconds to have passed until you heard the thunder ?

1140 ...rate of sound multiplied by
12″...the time elapsed.
5280)13680(2 miles.
10560
3) 3120
1040

Ans.—2 miles 1040 yards.

The more still the air is, the more easily is sound heard through it. Hence, in the Arctic regions, where the air is both dense and dry, and quite still, two persons may converse together over the ice, although separated a mile from each other. We thus hear distant sounds better in winter time than in summer, at night better than by day, and in fine weather rather than in moist or foggy air. However, the speed of transit diminishes with the temperature.

EXPERIMENT 6.—That sound requires something dense to convey it, will be evident if a bell is rung inside the receiver of an air-pump when the air has been exhausted. This experiment may be tried by putting a musical snuff-box inside the receiver. The sound will be heard so long as the air remains, but on the receiver being exhausted, no sound can be perceived.

EXPERIMENT 7.—The speed of sound varies in different gases, being slowest in carbonic acid gas, and most rapid in hydrogen. A very interesting set of experiments may be tried by blowing the different gases from a bladder through a whistle or organ-tube. The sound produced by hydrogen is very much shriller than that produced by air.

The passage of sound is much quicker through solids than through air. Indeed, water is a much better conductor than the atmosphere. It is customary for divers to communicate their signals by simply striking the sides of the bell by means of a hammer. The sound is distinctly heard, and the signal at once attended to. We shall describe the diving-bell under the section on Pneumatics.

Speaking-tubes are much employed for communicating messages ; and in most of the large warehouses and offices in London and other towns, they are used for the purpose of saving a vast deal of labour to the assistants. We must relate to our young readers an anecdote of an amusing prank which we played on a friend some years ago.

Being a little anxious as to the success of a new set of dissolving views, on their first exhibition, we had arranged a speaking tube of gutta-percha, reaching from a desk at which a friend was to read the description, to the place where the lanterns were, and which was sixty feet distant from the reader, and entirely out of his view. Everything went on well for some time, until, an accident happening to one of the gas-jets, the whole of the light was suddenly extinguished. We called through the tube to our friend to go on reading (as he had a shaded light); but unfortunately we had not told him of the existence of the speaking-tube, and he therefore was at a loss to know where the sound proceeded from. Being vexed at his not obeying our instructions, we very hastily repeated them, and called him by name, adding a somewhat strong expression of our opinion as to his stupidity. Still unaware of the source of the message, he imagined that another friend who was sitting beneath him had been the speaker, and the matter nearly led to a breach of the peace. When the views again were being shown, we determined to carry out the joke, and commenced making various noises through the tube. The effect was most laughable, for as our reader still could not guess the real cause of what he heard, he let his imagination have full play, and abruptly left the box. When the exhibition was concluded, we entered into full explanations, and matters ended in our all joining in a hearty laugh at his discomfiture, through our application of a little science in our arrangements.

We shall now speak of some interesting facts in reference to the conduction of sound through solid bodies, and its application to conveying musical and other sounds to a distance, and their reproduction on other or similar instruments.

Even amongst solid bodies there is a great variety with respect to their power of conduction. To give you an idea of this, we append a list of solids with the different rates of conduction compared to that of air. The table is that of Chladni, a philosopher, who has paid great attention to the subject.

If we indicate Air to convey sound at a speed of ...	1
Then Tin does so at a speed of	7½
,, Silver ,, ...	9
,, Copper ,, ...	12
,, Iron ,, ...	17
,, Glass ,, ...	17
,, Wood ,, ...	from 11 to 17

EXPERIMENT 8.—To illustrate the mode of conducting sound by means of wooden rods, the following experiment may be tried. On the end of a rod of wood, say twelve feet long and *half an inch thick*, place a musical snuff-box, and holding the

other end between the teeth, you will find that you can "hear" the music perfectly, although the ears may be stopped by the fingers.

This is owing to the transmission of the vibrations from the box to the teeth through the solid wood. Our young friends must note this as a new means of "hearing" by the teeth.

Experiment 9.—Hold a piece of iron (say the poker) by means of a string between the teeth; close the ears, and let a friend strike the poker—the sound will be distinctly heard.

Experiment 10.—Engineers use this method for the purpose of ascertaining the equal passage of steam into the cylinders of steam-engines. Thus, place one end of a ruler at the outside of the cylinder of a steam-engine, and the other end between the teeth, the ears being closed, you will be able to detect the passage of the steam from the slide-box at every stroke.

Experiment 11.—The stethoscope is used for detecting any irregularity of the action of the heart, and is employed on the outside of the chest, exactly as we mentioned in our last experiment. A practised ear can soon detect any symptom of disease, just as the engineer may discover an inequality in the supply of steam.

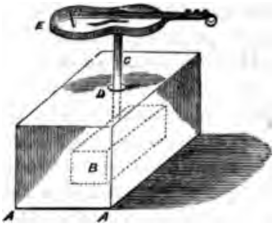
By combining what we will call a "diffuser" of sound with a conducting-rod, music may be conveyed from one room to another with perfect ease.

Experiment 12.—Place inside of a small deal box another one, and between the two place a fold of baize or flannel. If a musical snuff-box is now placed in the inner one, you will not hear any sound from it. Now bore a hole through the top of the two boxes and place a deal rod, say three feet long, so as to have one end resting on the musical-box, and the other extending upwards in the air—you will still hear no sound. Place at the top of the outer end of the rod a violin, or empty box of any kind. The sound will now be diffused through the room, but the moment you remove the violin all sound will cease. Fig. 4 illustrates this experiment.

You will thus observe that although the sound is conducted by the rod from the musical box, still it is not diffused through the room until the violin is in contact with it. In the piano and harp we have what are termed "sounding-boards," whose object is to spread the sound on all sides.

This interesting experiment was expanded into a most ingenious arrangement, called the Telephonic Concert, by Professor Wheatstone, and introduced into the London Polytechnic in 1856; when Her Majesty, H. R. H. Prince Albert, and other members of the Royal Family honoured the establishment by a visit, during which this peculiar arrangement formed a leading feature of the evening's entertainments.

Fig. 4.



A A, outer deal boxes enclosing
B, the musical box.
C, deal rod through the hole D, resting on the musical box.
E, violin for diffusing sound.

In the basement of the building, a piano, violin, violoncello, and cornopean were placed, and from each of these instruments were deal rods passing, and continued through two floors until they arrived in the upper lecture theatre—a height of about forty feet. On the upper end of the rods four harps were placed, but violins answered just as well. These were so arranged that they could easily be lifted on or off the rods.

As the performers played beneath, the sound was conducted by the rods to the harps, which diffused the sound, and thus you would hear, to the great surprise of a stranger, the sound of piano, violin, violoncello, and cornopean, coming from the harps. This used to be a sore puzzle to those who were not initiated. You will, however, easily understand it by remembering that you obtained, by means of the violin, the sound of the musical box in our last experiment. In fact, instead of these harps, empty boxes would have answered as well. On lifting the harp from any rod, the music instantly ceased from that one.

We attempted the conduction of the human voice by having four singers, whose mouths were placed nearly in contact with the sounding-board of a piano. This produced a strange but pleasing effect upstairs, for the audience heard a "quartett" proceeding from a harp; or, if you please, four human voices out of a piece of wood. This experiment often succeeded *too well;* for owing to the ludicrous appearance of the singers, with their heads together, and sometimes bumping against each other, the concert was often terminated by roars of laughter, every *sound of* which proceeded to the upstairs room, and was presented to the audience, most unwittingly, as another proof of the conducting power of wood with respect to sound.

We have since then tried a variety of experiments, and succeeded in bringing the music round curves and bends from one room to the other on the same floor, but the result is not so successful as when the rods are vertical. The head-piece to this section (page 241) illustrates the conduction of sound from the parlour to the drawing-room of a house, showing the rod resting on the sounding-board of a piano, and ending with a harp on its other end, to diffuse the sound.

A vast variety of interesting applications of these principles could doubtless be made beside those we have given. They are two of the chief with which we are acquainted.

THE REFLECTION OF SOUND.

We proceed now to inquire into the cause of echoes, and the effects observed in what are called "whispering-galleries," and remark that sound, like light and heat, can be easily reflected, by proper arrangements.

An echo may be produced by the reflection from a flat or a curved surface. The two reflections take place when any sound is produced in an arched tunnel. The two sides reflect, and so also does the roof; but in the latter case there is a point perfectly analogous to the focus we spoke of under the head of Light. (See page 196.)

Place two large reflectors at a distance from each other, and let a friend whisper in the focus of one whilst you place your ear at the focus of the other. You may thus hear the slightest sound, although any amount of noise may be going on around you, provided the two reflectors have their faces exactly facing each other.

Two of these, in the London Polytechnic, which are about six feet in diameter, are placed at the top galleries in the large hall. On one occasion we observed a lady and gentleman sitting together exactly in the focus of one, whilst we were accidentally in the focus of the other. The hall was well filled, and much noise was made by the machinery, &c., but we heard some most endearing expressions pass between them, although they were about 100 feet from us. We advise all "engaged" young ladies to be cautious how they trifle with scientific laws, for in such cases let them be assured that their vows of eternal affection may be heard in certain places by more than the person for whom they are intended.

Any curved even wall becomes what is called a "whispering gallery." The most noted of these is the one in St. Paul's Cathedral, London, where the slightest whisper may be heard, although the two trying the experiment may be on opposite sides at a great distance from each other.

By an application of the laws of sound, a very amusing arrangement can be made, called the "invisible lady."

It consists of a globe of metal to which four trumpets are attached, and from these proceeds a tin tube into an adjoining room. On whispering into one of the trumpets any question, the confederate immediately returns a suitable answer through another one.

Experiment 13.—We can suggest a very simple arrangement of this sort to our young friends. Obtain a large plaster of Paris head from one of the Italian makers, and put it in such a position that a pipe running from it may not be seen. Now fix in the mouth and ear a piece of gutta-percha tube, the two being joined neatly to one long tube. They should be not less than half an inch in diameter. Fix one of the ends of the tube in the ear of the figure, which must be hollowed by cutting out the plaster with a knife. The other end should be fixed in the mouth—of course both *inside* the head, so as to be out of sight. The long tube joined to these is to be taken into a room adjacent. Fig. 5 illustrates our plan.

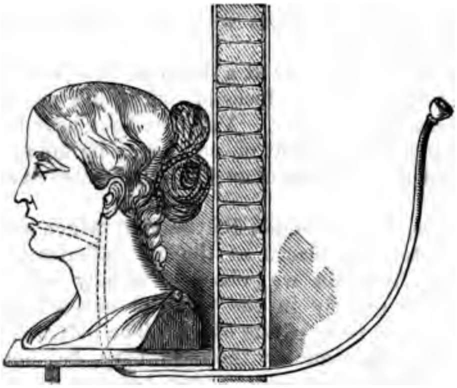


Fig. 5.

A confederate must be in another room, for the purpose of receiving the message, and of giving an answer, which he does through the mouth-piece observed on the right-hand side. The message or inquiry is sent by the *ear* of the bust, and the answer received from the mouth.

This little contrivance may be made a matter of great amusement if you take care to have a witty, lively individual as the "lady." It affords plenty of fun for young folks, who are extremely puzzled to know where the answer comes from.

The noise produced by putting a shell to the ear is an instance of the reflection of sound by a curved surface. The inside of the shell acts as a reflector.

Many ingenious inventions have been made, such as the speaking-trumpet, the ear-trumpet, the sounding-board over a pulpit, a peculiar construction of concert rooms, &c. &c., all of which owe their success to the principles of the communication of sound by reflection we have just explained.

The human ear is a beautiful and delicate contrivance, every part of it showing evidence of design. The outside is arranged to collect sound; the tube proceeding inwards to convey it; the drum is placed so as to form a kind of diaphragm between the inner and outer parts. The ear is protected by hairs and a wax-like substance, which prevents the ingress of dust and insects.

The following facts in reference to the passage of sounds, echoes, &c., may be interesting to our young friends, referring as they do to many daily occurrences.

Distant sounds travel best over smooth surfaces. We have already named the ease with which persons can converse with each other over the ice in the Arctic regions. In the same way sound travels on the surface of water much better than on land; and it is no uncommon thing, when out six or eight miles at sea during a still night, to hear the music of the evening bells as it comes fitfully "over the sea" from some village church near the edge of the shore.

The sound of cannon when being fired may be distinctly heard at a great distance. We have read accounts of the reports being heard at a distance of sixty miles. We have often listened to the sound of the guns, at a distance of twelve miles off, during the practising days of the Woolwich garrison.

If you lay the ear close to the iron rails of a railway, you may detect the sound of an advancing train long before it is in sight.

If you station a friend at a long distance from you near a length of iron railings, the sound produced by a stick striking them will be conveyed with great ease by the metal, although the same sound would have been entirely lost if simply conveyed by the air.

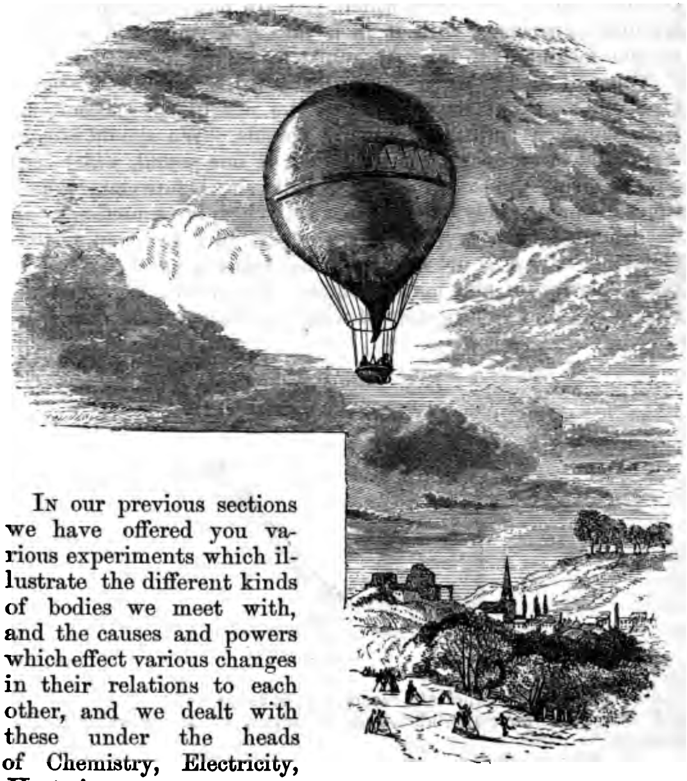
The rolling sound of thunder is caused by the echo produced between the clouds and the earth. Even the report of a cannon will sound like thunder on a cloudy day, owing to the successive reflection of sound. If you make a single exclamation in a long tunnel, you will find a similar effect produced.

Sound is not only conducted through the air by means of echoes or reflections, such as we have just referred to, but also by the solid earth. Thus you may hear a miner's pick at each stroke on the rock at a considerable distance, and in circumstances which would render it impossible that the sound could travel otherwise than through the rock, by placing your ear against its surface. We have noticed this effect at Clifton, near Bristol, and also in many other places where quarrying is being carried on. Sappers are sometimes detected by the besieged in this way, the sound of their tools in the tunnel being propagated through the earth.

A very singular effect may be observed by sitting near a post on which the telegraph wires are suspended. If a gentle breeze is passing, the wires vibrate and produce a sweet musical sound, reminding one of the effects of the Æolian harp. The effect depends partly on the tension of the wires, and the sound varies in strength with the force of the breeze.

We shall now conclude our remarks and experiments on Sound, and, having endeavoured to acquaint you with some of the leading facts in relation thereto, must here bid farewell to what we have called the "forces," or agents on whose action the numerous occurrences and changes of daily life depend.

EXPERIMENTS IN PNEUMATICS.



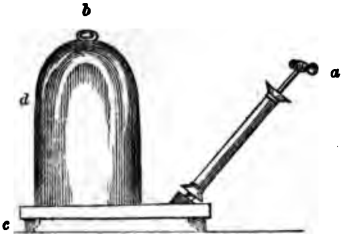
In our previous sections we have offered you various experiments which illustrate the different kinds of bodies we meet with, and the causes and powers which effect various changes in their relations to each other, and we dealt with these under the heads of Chemistry, Electricity, Heat, &c.

We next proceed to enumerate experiments of an entirely different class. In these we shall endeavour to show you what laws both gases and liquids obey when at rest or in motion; and we shall also speak of various applications of these laws, such as pumps, barometers, diving-bells, balloons, water-wheels, &c. We ought also to point out to you the distinction between the objects of *Chemical* and *Physical* Science. The former deals with parts, or the atoms of bodies, showing their different natures and composition, whilst "physics" treat on bodies in the mass, and on the effects they may produce when acted on by what are called forces.

The term pneumatics is derived from a Greek word, signifying "spirit," or air; and it is applied to that branch of science which refers to the weight, bulk, and movement of gases. Now, common air is that with which you are most acquainted, and we shall experiment with it in a variety of ways, and we hope in such fashion as to interest you.

You will require an air-pump for many of our experiments. One of these you may obtain at the instrument makers', for from eighteen shillings to many pounds. We should recommend you to purchase one at a cost of one pound, which will answer for all the experiments we shall bring before you. Sometimes air-pumps may be purchased very cheaply at auction sales, but we must warn you, that if every part, such as pump, piston, plate, and valves, is not in good order, you can never succeed in the experiments you may attempt. Fig. 1 will give you an idea of the kind of air-pump of which we have just spoken.

Fig. 1.



a is the pump by which the receiver, *d*, is exhausted.
b, a small screw which allows air to return, by its removal, into the receiver.
c, the plate on which the receiver rests.
d, the receiver in which your experiments are carried on.

Presuming that you have purchased an air-pump, we proceed with our experiments, and any further apparatus you may require we shall describe farther on.

EXPERIMENT 1.—*The Atmosphere has Weight.*—To prove this the following simple experiment may be tried. Cut a piece of *thick leather* into the shape of a five-shilling piece. Make a small hole through it in its centre, and through this pass a piece of string, a yard long, with a knot, and one end of which must rest inside the leather. Soak the latter in cold water till it is perfectly soft, and now holding the further end of the string in the right hand, press the leather on a piece of stone weighing, say twenty pounds, until every part of the leather fits tight to the stone's surface. Raise the leather (if you can) from the stone; but this you will not be able to do; because having pressed out the air between the stone and the leather, you have left between the two a "vacuum," or empty space. Now, owing to the *weight* of the air on the top of the leather, it is kept firmly fixed to the stone; and although the latter weigh several pounds, still you can easily raise it from the ground, owing to the pressure of the air on the leather surface.

EXPERIMENT 2.—You will at once perceive from this that the air has weight; we shall, however, adduce another illustration of this fact. Fill a wine-glass *completely* with water, and slide on to its surface a card large enough to cover the entire rim of the glass on every side. Now hold the glass in the right hand, and placing the fingers of the left hand on the top of the card, dexterously turn the glass upside down. You will find that the card will not fall down, but will appear to keep the water inside of the glass, although the latter is inverted.

This experiment seems to be the reverse of No. 1—and so it is in some respects; but from the two you will learn that, not only does the air press downwards, but also upwards. In fact, you will see that the air presses in *all* directions with great force,—indeed, to the extent of nearly fifteen pounds on the square inch. In other words, if you cut a piece of card exactly an inch wide and long, and took the air from beneath, the card would have to sustain a weight of about fifteen pounds; and on every part of the earth's surface at a level with the sea there is a weight pressing on it to this extent.

But you will at once say that you cannot feel this weight on your body. This is quite true, and is owing to the fact we have already mentioned,—that the atmosphere presses equally in all directions. You sustain the same pressure on the inside as on the outside of the body; but if you take either pressure away, the other will be at once evident, as we shall see by our next experiment.

EXPERIMENT 3.—Procure from the glass-maker's a cylinder of glass, three inches wide and four inches deep, of the shape shown in figure 2. Each rim must be carefully ground, so as to present a perfectly flat surface. Grease the lower end with some tallow, and press it firmly on the plate of the air-pump, so as to exclude all air from the edges. Then press the hand on the upper part, so as to entirely cover it, and with the other hand exhaust the air inside the glass. The moment you commence to work the pump, the air *in* the glass will be taken from it, and that outside will begin to press on your hand. You will shortly find that you cannot remove your hand; and the reason is, that the external air is pressing on it with a force of fifteen pounds on each square inch. Supposing your hand to cover the surface of the glass, which is equal to about seven square inches, the weight on the back of your hand will be no less than one hundred and five pounds. Fig. 3 illustrates the mode of carrying out the experiment.

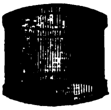


Fig. 2.

As you rise above the level of the sea, so the weight of the air decreases; and presuming you could arrive at a height of forty-five miles, there the air has no weight; in fact, that distance is believed to be the limit of our atmosphere.

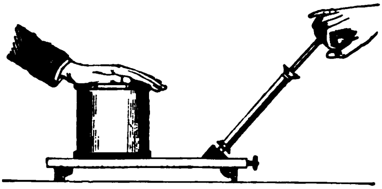


Fig. 3.

Experiment 4.—Over the glass cylinder used in the last experiment tie very tightly a thick bladder, and allow it to dry. Then place the glass as in fig. 3, and pump out the air it contains. You will find that the bladder is depressed in the centre, and after a few strokes of the pump-handle a loud report will be given, owing to the bursting of the bladder from the pressure of the air on its outside.

Experiment 5.—We shall repeat here an experiment mentioned under the section of Heat. Boil some water in a thin tin canister, until steam issues from a stopcock soldered into some part of it. Presuming that it is air-tight in every other part you may close the stopcock, and throw cold water on the vessel. It will instantly collapse, owing to the enormous weight *it has to sustain.* If your cylinder is twelve inches high and three inches in diameter, the air will press on it with a weight of eighteen hundred and fifty pounds.

This experiment will explain why steam-boilers can burst *inwards*, instead of outwards; for if a steam-vessel is sinking, the water rushing in on all sides condenses the steam of the boilers, and as in most cases their safety-valves only let *out* steam, they instantly close on the steam being condensed, and the boiler at once collapses. Persons climbing high mountains, or ascending in balloons, often spit blood—sometimes it rushes from the ears and nose, owing to the external pressure being removed, and the internal pressure acting on the blood-vessels forces out the fluid.

Experiment 6.—The latter effect may be illustrated by placing a shrivelled apple inside the receiver of the air-pump (see fig. 1). The receiver must have its ground edge greased with tallow, and it must then be carefully pressed on to the air-pump plate. Having all arranged, commence to work the pump, and you will find that the air inside the skin of the apple will press outwards and make the fruit to appear as if it had just been plucked.

Experiment 7.—Try the experiment with a bunch of raisins, instead of the apple: you will find that the raisins are at once converted into grapes! You will succeed better in this experiment by first moistening the raisins with a little warm water.

Experiment 8.—A very ingenious mode of illustrating this result, is by placing a piece of soft wood on the top of a glass jar, open at both ends. The wood is made in the shape of a basin, and is filled with mercury. On placing the jar over the air-pump plate, and pumping the air out of the glass, the mercury is forced into the jar, and should fall into a basin ready to receive it. We name the experiment, because it is often shown at lecture-tables, but advise you not to try it, for you will most likely spoil your pump. If any mercury runs into the little hole in the centre of the plate, you may almost be certain that your pump will be injured, owing to the mercury forming an amalgam with the solder used to attach its various parts. We have seen two splendid air-pumps completely ruined by this experiment. The reason of this you will learn by referring to our Chemical section under the head of "Mercury"

BAROMETERS.

We are enabled to construct an instrument for *weighing* the air, by applying the lessons we have learned in our former experiments; for if the air presses on everything with a certain force, liquids will naturally escape from its action, if they can find a place where there is no pressure. This place, or "vacuum," is always found in the top of the glass tube of the common weather-glass, for reasons we will now explain, simply mentioning that these instruments are called "Barometers," from two Greek words which signify "weight-measures."

Experiment 9.—Place a long glass tube in a glass of water, and at the other end draw out the air of the tube by the mouth. As you "suck" the air out, the water will rise, because you have produced a partial vacuum in the tube, which is immediately filled by the water rushing in, to take the place of the air.

If you were to try this experiment with a tube thirty-six feet long, and pump the air out of it by means of an air-pump, you would never be able to draw the water up so as to completely fill the tube, because a column of water about thirty-two feet *high* weighs about the same as a column of air forty-five miles high. Indeed, if you were to fill such a tube, sealed at one end, with water, and then place your hand on the open end, so as to prevent the water escaping, and were then to put the open end into a pail of water, some of the fluid would run out, but the greater portion would remain. At the top of the tube there would be a vacant space; and if you were to mark the side of the tube, where the edge of the water appears in its upper part, and to proceed daily, for a week or two, to do this, you would rarely ever see the water at the same height in the glass, because the weight of the air varies continually. To measure these variations is the object of barometers.

The one we have described is called a water barometer; but as, for many reasons, it would be a most inconvenient form, we shall explain how a simple one may be constructed by using mercury, which, weighing, as it does, only a twelfth part of the same bulk of water, affords us an instrument which, not exceeding a yard in height, serves far better than the water barometer of twelve yards high.

Experiment 10.—*To make a Barometer.*—Purchase a piece of glass tube a yard long and an eighth of an inch in the bore. Seal one end of this, by holding it at two inches from the end in *the flame* of a spirit-lamp or a gas-flame, and, when red-hot, pull the short piece away from the long one. The hot part will get narrower, until you may entirely close or seal up its end. Hold this end in the gas-flame until it presents a rounded appearance. Gradually remove it from the flame, so as not to cool it too rapidly. When cold, pour in some mercury, until the tube is *completely* filled, and holding it in the right hand, place the little finger of the left on the hole. Invert it thus in a cup holding some mercury. You will immediately find that part of the mercury will fall out, and a vacuum will be left at the upper end.

Now support this by means of a stand, or you can place the cup on a bracket against a wall, and fasten the tube in an upright position, by means of a couple of staples. This simple apparatus is a barometer, and will answer every purpose of one. Compare it any day with another instrument which has a scale attached to it, and ascertaining the height of the mercury, and marking a scale on paper, of inches, half and quarter-inches, paste this so that the level of the mercury in your barometer is at the same height in your scale as on the one you have compared it with, and your arrangement will be complete. Another mode of making the scale is to place a yard stick whose lower end shall be level with the lower end of the tube holding the mercury. The level of the fluid at the top of the tube will then appear opposite to the number of inches on the yard stick which corresponds with the real height of the mercury in any ordinary barometer.

The whole affair will cost you not more than half-a-crown; and we can, speaking from our juvenile experience, mention no instrument you can make that will excite so much interest in your mind, if you make a daily habit of watching this rough barometer, and of noting down in a copy-book the height of the mercury. You can purchase a thermometer for one shilling, and by observing the temperature at the same time, and noting it down also, you will add to the value of your observations.

To assist you in this, we give a skeleton heading, including other matters, which you can copy into the head-line of your note-book as a guide, and for the sake of uniformity.

Date.	Time.	Barometer.	Thermometer.	Wind.	Weather.
Nov. 15, 1860.	9 A.M.	29·50.	43·0	S.W.	Fine.

You will observe that we have added an example. It gives you all particulars of the weather at the moment this is being written. The height of both barometer and thermometer is always expressed, when there are fractions, in decimal parts. Thus our barometer, at this moment, shows that the mercury is at twenty-nine inches and a half high. The thermometer registers 43° of temperature.

You may add another column for remarks as to whether there was hail, snow, rain, or other phenomena.

It is very true that your observations will be rather rough; but, although not truly scientific in their strictness, they have the double advantage of calling out your powers of observation, and it is by no means unlikely that if you keep your notes by you, they may turn out of great value in the course of time. We have been greatly indebted in some respects to our observations, taken exactly in this way during our younger days.

Fig. 4.

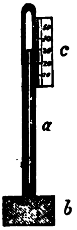


Fig. 4 illustrates the arrangement we have just described, where *a* represents the tube holding the mercury.

b, the cup containing mercury, in which the tube *a* stands.

c, the scale marked off in inches and parts of an inch.

We might have added a "vernier," by which you could have divided the scale of inches more correctly; but, as we should have required some space to describe it, we shall leave it to you so to cultivate the eye as soon to enable you to register any part of an inch not less than one-tenth.

We will now endeavour to explain to you the reason of the daily changes which take place in the height of the mercury. During your visits to the seaside, you will have frequently noticed how the sea often appears covered with waves. If you were to cut one of these lengthwise, you would, of course, find that the ends were far higher than the middle of the wave, measuring, of course, from a level line beneath them. If you were to go a step further, you would also, of course, find, on weighing the water contained in a column cut from the top of the wave, that it would exceed that cut from the centre, both, of course, being of the same breadth, although of different height.

Now, what is true of water is also true of air. There are *immense* waves in the atmosphere; and, just as the air-waves vary, in the manner we spoke of in the case of the water-waves, so the mercury in your barometer rises and falls, acting, as it does, like a counter-balance to the weight of the air. You may, if you please, compare the atmosphere and the mercury in the tube to two scale-pans, which will stand level or otherwise, just as they have equal or different weights in them.

The reason why the barometer affords an indication of a change of weather is, that when the air becomes less dense the vapour of the clouds generally becomes condensed, and so produces rain. Thus, on the top of a high hill, where the air is much rarer than at the level of the sea, you will often find a dense cloud; and if you were to pass through this, as we have often done ourselves, you would soon find the effects of its condensation in the form of a fine rain. Generally speaking, the rarer the air is, the lower the clouds hang; and, of course, the lower will the mercury fall in the barometer-tube.

To give you an illustration of this, we remind you of what you must often have noticed whilst standing on loose stones or rocks whilst the waves are dashing between them. The still water gradually rises as the wave comes towards shore, and falls again when it recedes. In like manner your barometer indicates the rise and fall of atmospheric waves.

When the air is dense, the clouds fly higher, and the mercury rises at the same time. Even the smoke from a chimney is an excellent indicator of the weather; for just as the atmosphere is light or dense, so the smoke falls or rises, as it issues from the chimney-pot.

We need scarcely tell you that the words "Rain," "Fair," &c., generally engraved on the plate of the house-barometer, can only give very rough ideas of the probable state of the weather. We just state that a *rising* mercury indicates the advent of fine weather, and the more gradual the rise, the longer the fine weather is likely to last; the same rule holds good with respect to bad weather indicated by the fall of the mercury.

The barometer can indicate a coming storm. If the mercury falls suddenly, a heavy gale of wind is sure to follow. During the severe storms at the close of 1859, these indications being attended to by many commanders of vessels were the means of saving many lives; whilst their neglect produced the most heart-rending consequences around the coast. At the present time most of our coast fishing-stations are supplied by barometers, which are erected close to the piers or landing-places.

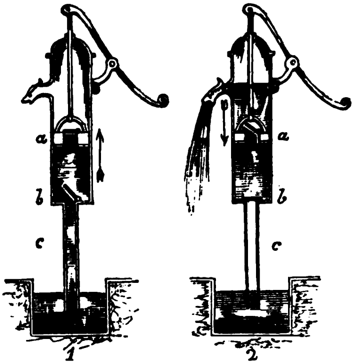
The force of the wind is judged of by what is called an anemometer; but we refrain giving any description of this instrument, for want of space.

PUMPS.

The common pump is constructed on principles such as we have already explained above. We shall suggest some simple experiments, which will give you an idea of its construction and use.

EXPERIMENT 11.—Procure a common syringe, and supposing the piston or plunger fits tightly inside the cylinder, you will be enabled to draw water into it on pulling the piston upwards from the jet; but allow the piston, or as it is called the plunger, to fit the cylinder loosely, and, owing to the air escaping to the lower side as you draw it up, you will not succeed in drawing in water. Fig. 5 illustrates the arrangement of the common pump, and also indicates the different parts of it, and their names.

Fig. 5.



No. 1 represents a pump in which the piston is being *raised.*
a is the piston, or plunger, having a valve represented as *shut.*
b is the valve *open*, through which the water is passing from *c.*
c, the pipe through which the water rises from the well.

You observe there are two valves in the pump, one open and one closed.

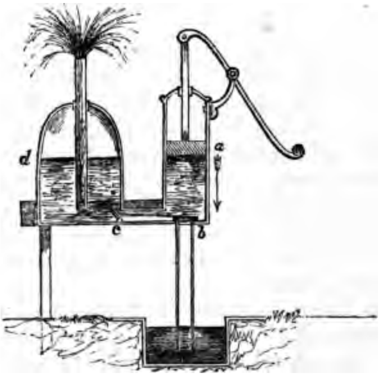
No. 2 represents a similar pump, only that in this the piston, or plunger, is being forced down. The valves at *a* and *b*, you will observe, are in different positions to those represented in No. 1.

The ordinary pumps, of all sizes, are constructed on the above *principles.* The air-pump, which we have already described, is similarly arranged, but of course the workmanship is of a far higher kind.

Whilst speaking of the barometer, we stated that water would not attain a higher *level* in a vacuum than about thirty feet. For this reason it would be impossible to make a pump draw water directly from a deep mine. Other arrangements are employed: sometimes several pumps are erected over each other, and worked by long rods reaching from the beam of a steam-engine; or, occasionally, force-pumps are used.

The force-pump is a common pump, to which an air-vessel is attached. The water is forced into the air-vessel, and is afterwards driven out of it with great power. Fire-engines are simply large force-pumps. Fig. 6 illustrates a force-pump such as is often employed in private houses.

Fig. 6.



a represents the piston, or plunger.
b, the lower valve.
c, a valve opening outwards from the cylinder.
d, the air-vessel.

At the level of the sea, water boils at a temperature of 212°; but if you try the experiment of boiling it on the top of a high mountain, it will boil at a much lower temperature, owing to the pressure of the air being less. The height of mountains may be ascertained by noticing the temperature at which water boils at their summit.

EXPERIMENT 12.—*To boil Water in an Air-Pump.*—Put some warm water into a watch-glass, and place the watch-glass on the plate of the air-pump, under the receiver. On exhausting the air from the receiver, the water will immediately commence to boil.

Experiment 13.—*To boil Ether in Vacuo.*—Use a little ether instead of the water, and proceed as in the last experiment. The ether will boil at a temperature as low as freezing-point. You can repeat these experiments by using spirits of wine and other volatile liquids.

Experiment 14.—Boil some water in a Florence flask, and, corking up the neck, throw some cold water on the vessel. The water will recommence boiling, owing to the removal of the pressure of the air from the surface of the water.

Experiment 15.—In our last three experiments the liquids were quickly converted into vapour. When using the air-pump, you will always find a kind of steam suddenly formed after about the fourth or fifth stroke of the pump. This is the moisture which the air gives out, owing to its rarefaction. Hoar frost is caused by this moisture being frozen on the twigs of trees, &c.

Experiment 16.—Expose a piece of chloride of calcium (see our Chemical section under "Lime"); it will soon become moist, through absorbing the vapour contained in the air.

Experiment 17.—A piece of the long seaweed found at low water round our coasts makes a very simple arrangement for judging of the moisture in the air. In wet weather it becomes soft and damp, and in dry weather it is stiff and hard. These changes are owing to the presence of a salt of magnesia, which absorbs water from the air when largely present. This forms an excellent weather-glass.

Experiment 18.—Owing to the presence of watery vapour, long lines of string, if stretched tight in the open air during the daytime and left out all night, will be found broken by the next morning. The moisture causes the string to contract with great force, and so it is broken.

Experiment 19.—If, during wet weather, you pour some ether on a cloth resting on the outside of a dry Florence flask, the cold produced by its rapid evaporation will condense the moisture which the air inside contains, and the water will be deposited in small drops.

Experiment 20.—Damp beds may be detected by placing a common looking-glass inside them. If the glass is cooler than the bed, the damp vapour will condense on the face of the glass, causing it to look dull.

The steam and water found on our bedroom windows on a cold morning, the dimness of the windows in a railway carriage, and many other similar effects, are produced by the same cause.

In journeying through mountainous countries, you will often perceive a cloud resting at the top or halfway up the hill. This is caused by the condensation of the moisture the air contains, occasioned by the cold which is always felt in elevated places. On more than one occasion we have walked through one of the clouds, and arrived at the higher part of the hill, where we were able to look *down* on the cloud, instead of up to it, as we usually do.

ELASTICITY OF AIR.

All our young friends know that a piece of india-rubber, when stretched or pressed, will regain its old shape on being left to itself. This power is called elasticity; and we shall mention a few experiments showing that air has this property.

EXPERIMENT 21.—Put the finger to the jet of a common syringe, so as to close it, and now press down the piston. As soon as you remove the pressure the piston will be driven back, owing to the air being elastic.

EXPERIMENT 22.—Press between the hands a common bladder, or one of the india-rubber balloons sold about the streets. Although you may press it ever so tightly, still the air will regain its old space on your removing the hands.

The common bellows, the powerful air-engine, and many other such contrivances constructed for the purpose of compressing air and producing a blast, are made on this principle.

EXPERIMENT 23.—If you possess a condensing syringe—that is, one that will force air into a vessel instead of exhausting it—you may easily construct a fountain. One of these syringes we described in our Chemical Experiments under the head of the "Fire Cloud." Have a copper or strong tin vessel, made of the shape represented in fig. 7, and having a pipe in its centre which reaches nearly to the bottom of the inside of the vessel, and to which a stopcock is fixed. Fill the vessel three-parts full of water, and then force air into it by means of the syringe. The air will be compressed; and if you now close the stopcock and screw on a small jet, removing first the syringe, you may obtain a fountain which will play so long as the pressure of the air inside exceeds that of the air outside. The air-vessel of the force-pump (fig. 6) acts on the same principle.

The air-gun sometimes employed by poachers, and also for rook-shooting, simply consists of a barrel to hold the shot, and an air-vessel into which a large quantity of air has been forced by means of a syringe. The air is allowed to pass out of the vessel, and striking the shot, it propels it with great force, owing to its elasticity.

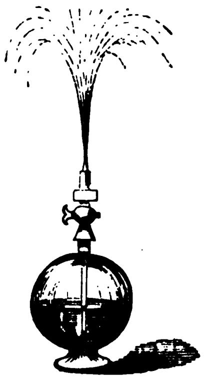


Fig. 7.

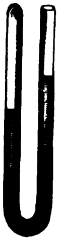


Fig. 8.

EXPERIMENT 24.—Bend a glass tube over the spirit-lamp, until it assumes the shape represented in fig. 8, and seal up one end. Now pour into the open leg some mercury. You will find that the air in the other sealed leg contracts into a smaller space. On removing the mercury, the air will soon regain its old bulk. This arrangement has been called a pressure-gauge, but when so employed has generally a scale, indicating the pressure, attached to it.

THE DIVING-BELL.

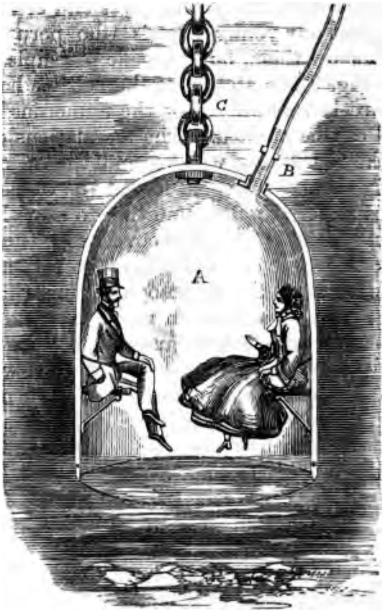
The diving-bell is an interesting application of this law of the elasticity of the air, and its principle may easily be understood by trying the following simple experiments.

EXPERIMENT 25.—Place a tumbler, full of air, upside down in a pail of water, and press it down a foot or so into the pail. You will find that the water does not fill the glass, but simply compresses the air. On raising the glass out of the water, you will find that the air it contains expands to its previous space.

EXPERIMENT 26.—Place a small piece of candle on a cork on the water in the pail, and then place over it the glass receiver of your air-pump. You may now force the glass into the water, and yet the candle will burn, showing you that the air still remains inside the vessel. After some time the candle will be extinguished, owing to its having consumed the oxygen gas which the air contained. For this reason the ordinary diving-bell is supplied with air by means of powerful force-pumps, while the foul air escapes at the bottom of the bell.

Diving-bells are made of various shapes and sizes, according to the purpose for which they are required. A seat is placed inside, and the diver receives light through thick glasses let into the top of the bell. The force-pumps supply the air through a pipe at the top of the bell, and the diver makes any signal by striking the sides of the bell with a hammer. The

Fig. 9.



In the above engraving, A represents a section of the bell; B, the pipe by which air is supplied; and C, the chain from which the bell is suspended.

divers, being clothed in a waterproof dress, proceed from the bell. On their heads they wear a helmet, which is connected by means of a pipe with the bell itself, from which they draw their supply of air. A very singular effect is produced by the compression of the air as you descend in the water; you experience a singing in the ears, and sometimes a headache. We have been down twenty-five feet in the sea in one of these bells, but from the unpleasant effect we experienced we intend to content ourselves with one experiment. The divers soon get used to it, however; and as they earn good wages, the employment is highly sought after.

A diving-bell may be seen in the London Polytechnic, in which visitors may safely descend to a depth of ten feet, and without the least inconvenience. The ladies sometimes think that there ought to be something at the lower end of the bell, *to keep the water out;* but our young friends who peruse these pages will be able to show them, on scientific principles, that this is unnecessary. Fig. 9 is a section of the bell we have named.

We need scarcely remind you of the numerous uses to which the diving-bell can be applied. The foundations of bridges and breakwaters, the removal of wrecks, and the recovery of treasure, are among them. The gold lost at the wreck of the Royal Charter, in November, 1859, amounting to some hundred thousand pounds, has been nearly all recovered by these means.

EXPERIMENT 27.—A very amusing illustration of the elasticity of air is sold at the philosophical instrument-makers'. A small glass figure of a man, in which a little air has been left, so as to allow the figure just to float in the water, is placed in a tall vessel; and on the top of this, which is nearly filled with water, a piece of india-rubber is firmly tied. On pressing the india-rubber the air contained in the figure is condensed, and the figure sinks; on removing the hand, the figure again rises to the top of the vessel.

BALLOONS.

Passing from those applications of the laws of our atmosphere by attending to which we are enabled safely to descend into the water, we shall next consider the different plans which have been adopted in pursuing a reverse course; namely, that of rising in the air.

The first attempt made to navigate the air was by means of *fire-balloons,* as they were called. Large bags of various materials were filled with heated air. This was done by lighting fires in the cars, and the hot air rising into the balloon, being lighter than the external cold air, gave a power of ascending.

These arrangements were, of course, very dangerous, and several serious accidents resulted. Eventually it was proposed to employ hydrogen gas, and to make the material of the balloon of silk, varnished over, so as to prevent the escape of the gas. By referring to our Chemical section our young friends will at once learn how they may fill small balloons by means of hydrogen obtained from water. (See Experiment 39, page 23.)

Balloons of large size are filled with common coal-gas, which is much cheaper than pure hydrogen. The principle on which balloons ascend in the air is, that they weigh less than the same bulk of air. Such being the case, the balloon must necessarily be increased in size just in proportion to the weight they have to carry. We believe that the largest balloon yet constructed was one which could carry up eight persons.

Experiment 28.—The principle of the balloon may be better understood by your trying the following experiment. Sink a pound weight to the bottom of a tub of water; and by means of a string attach a bladder full of air to it, forcing the bladder to the bottom of the tub, and tying it to the weight. If the weight of the air-bladder and pound is less than that of their bulk of water, the whole will rise to the surface; the weight of course hanging beneath the bladder, just as the car does to a balloon.

Water-balloons, if we may so call them, are used for the purpose of raising vessels which have been sunk in tidal streams.

These are sometimes india-rubber bags, or large casks, which, being air-tight, are attached by means of chains to the sunken vessel at low water. As soon as the tide rises, the buoyancy of the casks is such as to float the vessel. The latter is then taken in tow by a steam-vessel until it touches the ground through want of depth of water; the process is then repeated until the vessel is brought to a convenient place for repair. The water in it is then pumped out, and being made once more water-tight, it is again fitted to float on the sea.

We happened, a few months ago, to be staying at a sea-port near which a vessel, laden with empty casks, had sunk. A portion of another and heavier part of her cargo had been removed by divers. She had thus been lightened, and one day, shortly after the tide had risen, the casks in her hold lifted the entire vessel out of the water to a height of several feet, much to the surprise of the men who were just about to return to their duties in the diving-bell.

Arrangements of casks, called pontoons, are employed by military men in forming bridges across rivers. On the casks planks are placed, and over these the heaviest *matériel* of the army may be safely and expeditiously passed.

In some cases, where there is not sufficient depth of water for a vessel to pass over a bar—that is, a bank of sand, &c. at the mouth of a river—chains are run under the keel of the vessel, and these are attached to large barges which have been made air-tight. The vessel is thus raised out of the water, and so is enabled to proceed to sea.

EXPANSION OF AIR.

In our section on Heat, we stated that all solid bodies expand, as a rule, on receiving more heat; and the law holds good with air and gases. We repeat an experiment which we have already named.

Experiment 29.—Fill a bladder with air, and after tying the neck tightly, expose it to the heat of a fire. The bladder will soon swell, and will very likely burst, owing to the great expansion which will take place.

Experiment 30.—Obtain a small bladder, and after filling it with air, place it inside the receiver of the air-pump, but so as not to touch the small hole in the plate through which the air should pass. Now exhaust the air from the receiver, and owing to the expansion of the air in the bladder, by the removal of external pressure, it will speedily burst.

The above experiments will give you a general idea of two methods of expanding air. That mentioned in Experiment 29 has been applied by Mr. Ericsson, of America, and others, for the purpose of obtaining a motive power by means of heated air. To some extent the attempt has been successful, but not sufficiently so to make the application of very general use up to the present time.

Amongst many other instances of the expansion of gases on the external pressure of the atmosphere being removed, we may instance the case of balloons, which, though only perhaps partly filled on leaving the earth, soon become distended on attaining a great altitude. This is often a source of great danger to aëronauts; and instances have occurred in which, owing to the escape-valve generally fitted to balloons having got out of order, the balloon has burst, and the aëronaut has met with a fearful death.

The subject of ventilation we have already referred to under the section on Heat. We may just remark, that any plan, to be successful, must be conducted in obedience to the laws of the expansion of air, &c., by the addition of heat. In all cases a gas becomes lighter by being heated, and so has a tendency to rise in the atmosphere. Hot air, for the same reason, always rises to the top of a room, and it is in that position that arrangements should be made for its escape.

COMPRESSION OF AIR AND GASES.

We need scarcely tell you that by compression we mean the act of forcing anything into a smaller space than that it usually occupies. The ordinary process of making soda water is an instance of the kind. Carbonic acid, with which we gave so many experiments in our Chemical section, is produced from chalk, and forced into water, which speedily dissolves or absorbs it. This is done under great pressure; in fact, the gas is compressed to a fourth part of its bulk, by means of steam machinery and pumps. On withdrawing the pressure—as, for instance, on taking the cork out of a bottle of soda water—the gas expands to its previous bulk, by virtue of its elasticity.

You will remember that we have already stated (see "Heat") that the different states of bodies are owing to the presence or comparative absence of heat. Now, when gases are compressed, they give out heat, as our next experiment will show.

EXPERIMENT 31.—*Heat and Light obtained from Air.*—Put a small piece of German tinder at the bottom hole of a condensing-syringe, having previously drawn the piston to the top. Now suddenly drive the piston down, and the heat given from the air contained in the cylinder will be sufficient to set the tinder on fire.

EXPERIMENT 32.—Put the finger on the hole at the bottom of the condensing-syringe, allowing a chance of only a little air to escape. On working the piston repeatedly, you will find that the cylinder becomes very hot. Now, that this is not owing to the friction of the piston against the sides of the cylinder, you may soon prove, by taking the finger away from the hole, and allowing the air to freely escape. In condensing the air into the bottle we described as used for the fire cloud experiment in the Chemical section, the cylinder of the syringe sometimes becomes too hot to be held in the hand.

EXPERIMENT 33.—When gases which have been compressed are allowed to escape suddenly, they produce cold by absorbing the heat from surrounding bodies. Thus, keep a bottle of soda water for some time in a room, so that it may gain the same temperature as the air of the apartment; then place a thermometer in a tumbler, uncork the bottle, and pour its contents into the glass. You will find that the mercury of the thermometer will fall, owing to the gas which is given off running away with the latent heat of the mercury.

Experiment 34.—Make two solutions, in separate glass vessels, of carbonate of soda and tartaric acid. Test their temperature; and when that is the same in each glass, place your thermometer in a third glass, and pour the contents of the glasses into it. You will find that the temperature falls rapidly; for, in this case, the carbonic acid existed in a *solid* state, and required to rob the water of much of its heat before it could retake the gas form, or aëriform state.

Experiment 35.—The most intense cold we can produce is by compressing carbonic acid, and then allowing it suddenly to escape through a small aperture. When it reaches the air, its sudden expansion requires a great amount of heat; and in drawing this from the atmosphere, so great a degree of cold is produced that the acid freezes into the form of snow. If some of this is placed in the palm of the hand, although producing cold, still it will do the hand no injury; but if pinched between the fingers, the solid acid will inflict a most serious wound, and the skin will peel off just as if the fingers had been burned. You will remember our remarks respecting the Arctic regions, under the head of "Heat," where we stated that a similar effect took place when metal instruments, &c., were allowed to come into contact with the skin.

Experiment 36.—If some of this solid carbonic acid is mixed with some ether, such intense cold is afforded as to permit large quantities of mercury to be frozen with ease.

Experiment 37.—If the mercury so frozen is thrown in a lump into a glass of warm water, the metal will take the heat so rapidly from the fluid as to instantly convert it into ice, and the expansion of the ice will break the cup into scores of pieces. (See our remarks on the expansion of water during freezing, page 166.)

The above experiments we have tried ourselves; but we must tell you that they are of the most dangerous kind. We have, however, no hesitation in relating them, because you will not likely be in possession of the apparatus necessary for the purpose. Our object has been to interest you by mentioning the facts. The carbonic acid is made in a very strong iron vessel, and received in another placed near it. The gas is compressed until it exerts a force of fifty atmospheres; that is, fifty times as much as the ordinary pressure of the air (see Experiment 1), so that every square inch of the vessel has to maintain a pressure of no less than seven hundred and fifty pounds on the square inch, or about nine times that of an ordinary locomotive boiler. Several patents have been taken out for the purpose of applying compressed carbonic acid and common air in place of steam. The idea at first sight seems very feasible, but you must remember that you cannot get all the power that you have expended in compressing air into suitable receivers; so that it is really more economical to employ the steam-engine instead. Besides, the compressed air requires very strong, and therefore very heavy vessels to hold it; and in no case could such be used stronger than sufficient to hold air having a pressure of 750 pounds on the square inch in an economical manner.

You will remember that one cubic inch of water expands into 1700 cubic inches of steam; whereas one cubic inch of air compressed as above would only expand to fifty times its bulk when set free.

There are several other objections to the use of compressed gases, which are, however, of too philosophical a character to mention here.

We shall next proceed to give you an explanation of the different parts of the steam-engine, merely remarking that, when compressed air or carbonic acid gas are employed for motive power, the common high-pressure engine is always used.

THE STEAM-ENGINE.

Although we cannot offer you many experiments in connexion with this interesting subject, we think a simple and untechnical explanation of the different parts and uses of the steam-engine will be instructive and pleasing to you. We shall, accordingly, endeavour to lay such facts before you as will tend to give a general idea of the reason why and how a steam-engine works.

There are three kinds of steam-engines employed at the present day; namely, the high and low pressure, and the expansive engine.

In the *high-pressure* engine the steam is used at a pressure much greater than that of the air. We have already said that the air presses with a force of fifteen pounds on the square inch. Now, in high-pressure engines the steam is made to press with a force of from forty to two hundred pounds on the square inch. The highest pressure, however, generally employed, is that of eighty pounds, and that chiefly in locomotive engines. In factories and other places the steam is generally employed at a pressure of forty pounds.

In the *low-pressure* engine the steam is generally of a pressure of about ten to fifteen pounds on the square inch, beyond the pressure of the atmosphere. By this we mean that if you were to allow such steam to press on one side of the piston of a syringe, and the atmosphere to press on the other, the steam would have the best of it by from ten to fifteen pounds for each square inch of the piston's surface.

In *expansive* engines the steam is used both at high and low pressure. In most cases the high-pressure steam is first used in a small cylinder; and when it is expanded, it is passed on to another cylinder of larger size, and is thus made to do double work.

In the high-pressure engine the steam is *thrown off into the air* when it has done its work. In the low-pressure and expansive engines it is *condensed into water*, and by the vacuum so produced an extra power of fifteen pounds on the square inch is obtained. This we shall explain more fully presently.

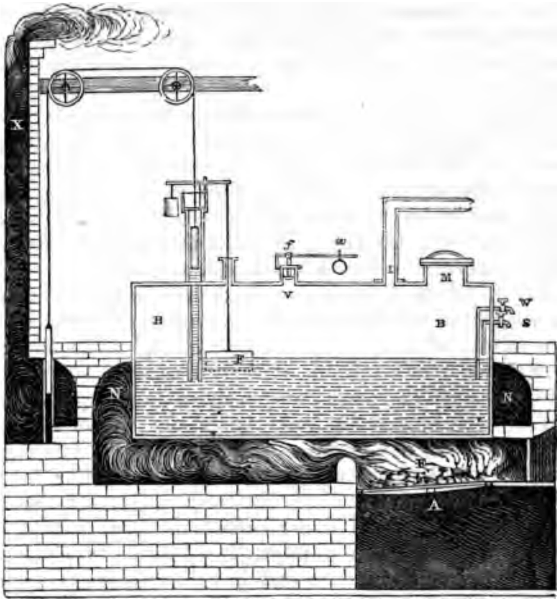
BOILERS.

For supplying steam to the engine, a boiler is of course required. These are generally made of iron, and are of all kinds of shapes. Some have the fire placed beneath them, some have a central flue in which the fire burns, and others, chiefly those used on board steam-boats, have immense square chambers, containing perhaps a thousand tubes, each ten feet long and two inches in the bore. Through these tubes the hot air from the furnace passes, and thus the steam-producing power of the boiler is enormously increased. These tubes are largely employed in locomotive boilers, and, in fact, are one of the most essential parts of them.

Our illustration (fig. 10) will give you an idea of the kind of boilers usually employed in stationary engines; that is, those erected for manufacturing purposes.

It is customary to have two safety-valves to each boiler on board steam-boats, one of which is locked up, and therefore cannot be over-weighted. This is a very necessary precaution, inasmuch as the engineer is often tempted to increase the pressure of the steam by weighting the valves, especially when there are opposition boats running on rivers.

Fig. 10.



A is the ash-pit of the furnace.

B, the boiler.

E, a fire.

F, a float, which indicates the height of the water in the boiler, and also admits a supply when required.

I is the pipe by means of which the steam passes to the engine.

M is the man-hole lid, by means of which a person can enter the boiler for the purpose of cleaning and removing the fur which is produced by the earthy matter contained in the water being thrown down.

N N are flues through which the hot air and smoke pass from the fire, round the boiler, and to the chimney.

W S are two cocks, having pipes inside the boiler. By means of these, the engineer can ascertain the height of the water in the boiler. That marked W should only allow the escape of water, and S should give steam, on being opened. If the water is too high, it would escape by means of S; and if too low, steam would escape by W. The engineer endeavours to regulate the supply of water so that it shall reach about half-way between the two pipes.

V is a most important part of the boiler; it is the safety-valve, by means of which the steam may escape when the pressure is too great. This valve is loaded at the end of the lever by a weight, *w*, which is fixed anywhere between *f*, the fulcrum, and the end of the rod. The farther the weight, *w*, is from *f*, the greater the pressure on the valve.

Nearly all the explosions of steam-boilers are caused by neglect of the safety-valve, or through its being purposely overweighted. We have been in the engine-room of steam-boats both on the Thames and Clyde during a race, and although it is an exciting affair, we have more than once trembled for fear of an accident. The safety-valves of steam-boilers are generally on deck in Scotland. On one occasion we were travelling all night, and whilst walking the deck were somewhat surprised to find that the speed of the vessel was rapidly increasing. It turned out that a cattle drover who was on board had chosen the top of the casing of the boiler as a snug place, from its warmth, and he had to sleep with one arm on the lever of the safety-valve. On his being removed the valve instantly rose, and the steam escaped with great violence, showing the extra pressure which had been caused in the boiler, owing to the extra weight on the valve of the countryman's body.

The safety-valves of boilers often "stick," as it is termed; that is, they become fixed in their seat. This is a frequent cause of accidents; indeed, only a short time ago, a vessel was blown up off Lowestoft, from the fixing of the safety-valve preventing the escape of steam whilst the vessel was stopping. We regret to say that several lives were sacrificed.

We can offer you some very interesting experiments which will explain the cause of boiler explosions in some instances.

Experiment 38.—Dip a piece of red-hot iron plate into a basin of cold water and immediately withdraw it; you will find very little steam produced.

Experiment 39.—Pour some water on to a red-hot plate, holding the latter slantwise, so that the water may readily run off. You will find, if the plate is *red-hot*, that the water will run off it in small globes like shot.

In either of the above experiments the water has assumed the spheroidal shape; that is, it has formed into round globes, round each of which is a coating of steam that entirely prevents the water touching the iron. On referring to page 178, under the section on Heat, you will find an experiment in which we have given directions for safely handling red-hot lead. Now, as we there stated, the metal, whilst red-hot, never touched the hand, owing to a coating of steam which was formed. The very same state sometimes occurs in steam-boilers. The metal gets red-hot, and the water is kept from it for some time by a thin coating of steam. If, however, the metal is allowed to cool down, as for instance by pumping in a quantity of water, then the coating of steam is lost, the water and the metal come into *contact*, and a fearful explosion ensues, by the sudden formation of a large quantity of steam. The reason of this you will understand by trying the next experiment.

EXPERIMENT 40.—Pour some water on to an iron plate, which is but a little hotter than boiling water. Instead of the water running off, as in Experiment 39, it will instantly fly off as steam, because you will have no thin protecting-plate between the fluid and the metal.

The "fur" often adheres to the body of the boiler. After a time it gets hard, and completely covers the metal. The boiler is thus allowed to get red-hot in that part; and if, by some accident, the fur perhaps cracks off, leaving the metal bare, the same result as we found in Experiment 40 at last takes place: steam is suddenly formed, and the safety-valve not being large enough to let off the whole of the extra steam, the boiler at once explodes.

EXPERIMENT 41.—It has been found by Dr. Faraday, that water, when entirely free from air, will scarcely boil; and it has been suggested that, owing to the air often being entirely driven out of the water in steam-boilers, the water does not readily pass into steam. If, however, fresh water is pumped in, the air so supplied with it instantly gives rise to the formation of steam, and so an explosion occurs. Our next experiment will illustrate this case.

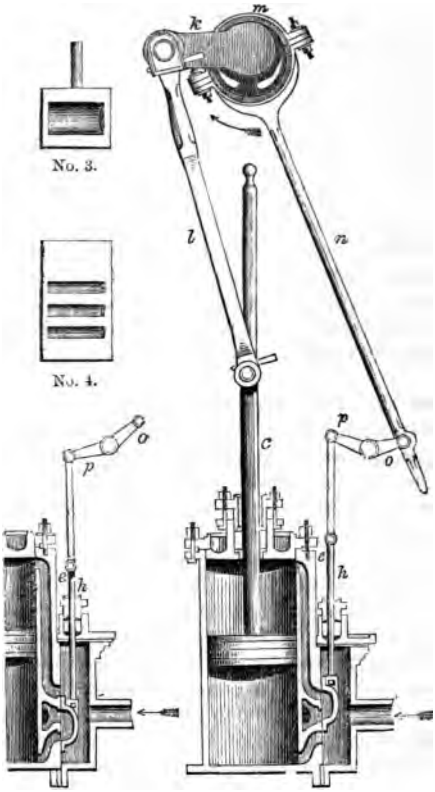
EXPERIMENT 42.—Boil some water in a Florence flask, and you will observe that, owing to the surface of the glass being smooth, the steam rises from the bottom in large and irregular bubbles. Now cast into the water a small piece of platina foil. Steam will be produced in quantities, and will rise regularly from the edges of the metal.

EXPERIMENT 43.—Repeat the experiment, by employing some iron filings instead of the foil. The steam will be produced in such quantities as to perhaps cause the flask to burst. It will be better for you to try this in an open glass or earthen vessel, lest you suffer injury from the bursting of the flask.

Having thus spoken of the construction and uses of steam-boilers, we shall next refer you to the engine itself; and to prevent the chance of confusing you by a multiplicity of details, we shall confine ourselves to the most essential parts of a high-pressure engine.

The principal part of the steam-engine is its cylinder. These are generally made of cast-iron, and are turned in a lathe until the inside is perfectly smooth, and even polished. Inside the cylinder is a piston, which fits it in every part, so as to prevent the chance of any steam escaping from one side of it to another. The cylinder and piston of the steam-engine are exactly like the same parts of your air-pump. Attached to the piston is a rod, which by means of another one communicates the motion of the piston to a crank. The upward and downward motion is thus converted into a circular one. We annex a diagram, which will give you a good idea of these different parts.

Fig. 11.



No. 2. No. 1.

In the above figure, No. 1, *c*, is the piston rod; *l*, the connecting rod; and *k*, the crank.

One of the most difficult parts of the steam-engine to young persons is the arrangement by means of which the steam is *admitted* alternately above and below the piston. This we will endeavour to explain to you. In your air-pump you will see that the air enters the cylinder by means of a valve at the bottom, and passes through the piston. In the steam-engine the steam is supplied through two holes, one at the top and the other at the bottom of the cylinder, and leaves by the same means. These holes are called the "ports," and you will observe their position in our illustration, Nos. 1 and 2. On the side of the cylinder there is placed, in a box, a valve called a D-valve, which works on the face of a piece of metal which has three holes, and which is generally cast with the cylinder. No. 3 represents this D-valve, and No. 4 the metal face with the holes in it. (See fig. 11.)

Now, the upper and lower holes are connected, by means of pipes, with the top and bottom of the cylinder, and through these the steam passes to and fro. The middle hole has a pipe passing off into the air, and through this the steam escapes when it has done its work.

By means of this valve the steam is admitted above and below the piston; and referring to Nos. 1 and 2, you will see the valve in two different positions. In No. 1, the steam-pipe from the boiler is in communication with the *bottom* of the cylinder, and the steam is entering it to force the piston *upwards*. In No. 2, the steam passing from the boiler is proceeding to the *top* of the cylinder, and is therefore pressing the piston *downwards;* and in both instances that part of the cylinder which is shut off from the steam-supply is losing its steam by the middle hole to which we have just referred.

You thus perceive that the D-valve does double duty. It not only permits the supply of steam, but also allows of its escape when done with. When the piston is at the top of the cylinder, the valve is at the bottom of its box, and *vice versâ.*

To the valve a rod, *h*, is fixed (Nos. 1 and 2), and by means of another rod it is connected with a lever, *p*, *o*, which is moved by an eccentric, as it is called.

Although we are obliged to use here the technical terms, still we fancy you will not have much difficulty in understanding the use of this ingenious contrivance. When the steam-engine was in its early days, the steam was admitted above and below the piston by a man or boy employed for this purpose. This was effected by opening two cocks. A youngster, however, who was engaged in this employment, was tempted by some of his companions to play the truant; but as he dared not let the engine stop, he hit upon the ingenious contrivance of tying a string with a weight hanging from it to the beam of the engine. To this string he tied the cocks we have just mentioned, and to his great delight he found that the cylinder could thus be supplied with steam by the working of the engine itself, independent of any attendance. Thus the boy, by his ingenuity, succeeded in that which had hitherto puzzled the engineers.

But to return to the eccentric. It is a circular plate of metal fastened on to the shaft of the engine, so that as the crank turns round this plate may turn with it. It is, however, not fixed on its centre, but out of it; hence its name. For instance, if you cut a piece of card of the shape of a penny-piece, and drive a pin through its centre, the card will turn round on the pin, just as a wheel does on its axle. Now, put the pin into any *other part* of the card than the centre, and you will find an exact representation of the eccentric of a steam-engine. This is illustrated in No. 1, by the letter *m*, fig. 11.

Round the eccentric is a strap of metal, which by means of the rod, *n*, is connected with the lever at *o*. This is done by means of a peg fastened on the lever, which fits in a notch cut out of some part of the rod, *n*, fig. 11.

The action of the eccentric is this: When it turns round with the shaft, it either pulls or pushes the lever, *o*, *p*. In No. 1, it has forced *o* down and *p* up; and as *p* is connected with the D-valve, that has been raised to the top of the box, and so allows the escape of the steam from the top of the cylinder into the open air. In No. 2, *o* has been raised and *p* depressed, and thus the steam is allowed to proceed to the top of the cylinder, whilst it is escaping into the air from the bottom. Thus you see the action of this ingenious arrangement, by means of which the engine supplies itself with steam, and so works continuously without the necessity of any human assistance.

Water is supplied to the boiler by means of a pump attached to another eccentric; and these pumps are generally of such a size as to supply a little more water at each stroke of the engine than is actually consumed in the form of steam. The regulation of this supply, of course, is part of the duty of the engineer.

We have endeavoured to express ourselves as clearly as possible in the above description, and trust that our young friends will be enabled, by a little study, to understand how each part of an ordinary steam-engine does its work.

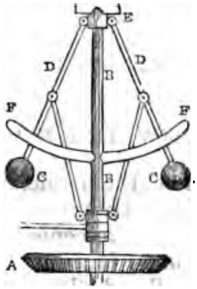
The steam is let into and shut off from the engine by means of what is called a throttle-valve. In small engines a common stopcock is used for the purpose.

A fly-wheel is attached to stationary engines for the purpose of regulating their speed. Without this the motion of the engine would be irregular, and, in fact, would be a succession of jolts, which would soon destroy the delicate machinery of a cotton-mill. If you should happen to be on board any steam-vessel which has only one engine, you may easily judge of the necessity of a fly-wheel in such cases by the following experiment.

EXPERIMENT 44.—Stand on tiptoe, with your face to the bows or stern of the boat. At each stroke of the engine you will find yourself suddenly thrown backwards and forwards. If you try this in a vessel with two engines, you will not have the same result, because they are so arranged that, whilst one piston is at full work, the other will be either at the top or bottom of its cylinder, and thus they mutually compensate with each other, and propel the vessel evenly.

The "governor" is another arrangement employed for the purpose of regulating the speed of the steam-engine. In large factories some portions of the machinery are continually being thrown on and off work, and thus the engine will at one moment be fully employed, and at another perhaps only half so.

Fig. 12.



A is a tooth-wheel, by which motion is produced in the governor. Next to it is the collar on which the rod attached to the throttle-valve rests.

B B is a spindle, on which the collar rises and falls.

C C are two heavy metal balls.

D D are two arms on which the balls hang, and which are connected by other two arms with the collar.

E is a hinge, on which the arms, D D, hang.

F is a slit or grooved piece of metal, which serves as a guide to the arms holding the balls.

Without the governor there would arise great danger; and we remember an instance where the governor being out of order, and some portion of the machinery having been stopped, the engine commenced working at a great speed, and eventually the fly-wheel broke. Its solid rim was projected into the mill, and several of the work-folks lost their lives. The governor consists of two balls hanging on arms, to which is attached a rod connected with a stopcock or throttle-valve in the steam-pipe. The faster the engine runs, the higher the balls rise. In so doing, they raise a kind of collar on which the rod from the valve rests. As this collar rises, so is the steam shut off from the engine, and thus its speed diminished. On this taking place, the balls again fall, the valve is opened, and more steam is supplied. You will perceive then the rising and falling of the governor-balls regulate the speed of the engine, by shutting off or letting on the steam. Fig. 12 is an illustration of one of the ordinary forms of a governor.

We have thus confined ourselves to the most essential parts of the common high-pressure engine. We need scarcely say that such are made of all shapes. In fact, it is impossible to give you an illustration of all of them, as their number is so great. The parts we have described are to be found in all such, and the study of our engravings will enable you to compare the different forms of engines with each other.

THE LOCOMOTIVE ENGINE.

One of the best known of all the different applications of the steam-engine, is that of the locomotive employed on our railways. Our young friends will at once recognise it as belonging to the high-pressure class of engines; indeed, a greater force of steam is generally employed on railroads than in any other way, most of the boilers affording steam of a pressure of eighty pounds on the square inch.

The engines of the locomotive are of the same kind as those we have just described, and are attached to the side of, or underneath, the boiler. Some years ago locomotives were made with four wheels, but those with six wheels are preferred at the present time.

The chief point of difference between an ordinary steam-engine and a locomotive, is that with the latter the boiler attached is of a very peculiar construction.

On opening the furnace-door of a locomotive, you will observe a square box which is called the fire-box, which is in fact the furnace which affords heat. Opposite to the door of the furnace *you will* observe a large number of holes; these are the ends of long tubes which stretch from one end of the boiler to the other, and are surrounded with water. The flame of the furnace runs through these, and the smoke escapes at the other end, into the funnel.

There is a very ingenious arrangement employed in the locomotive for the purpose of increasing the draught. The waste steam is brought, by means of pipes, from the cylinders, and is driven in a straight line up the funnel. As it thus escapes the air is drawn powerfully by it through the coals and coke of the furnace, and the combustion of the fuel is therefore carried on very rapidly. If it were not for this invention, it would be impossible to obtain sufficient steam to enable us to travel at the speed we do on railroads. So powerful is the draught, that lumps of burning coal as big as an apple are drawn through and blown to a height of ten or fifteen feet into the air, a result you may often see if travelling at night. Sometimes serious fires have been occasioned through these pieces lodging in hay, corn, &c., in adjacent fields. If you try the following experiment, you will gain some slight idea of the power of this steam-blast, as it is called.

EXPERIMENT 45.—Fix into the spout of a tea-kettle by means of a cork, a jet of glass, or even a piece of the stem of a tobacco-pipe. When the water boils and the steam issues forth very rapidly, hold a few feathers, or pieces of paper, just at the back of the jet, near where the steam is issuing from. You will find that a powerful draught is thereby created, and the feathers, &c., will be blown off into the air. You thus use a pressure not exceeding a pound or two on the square inch, whilst in the locomotive the pressure of the blast is enormously greater.

The tender of the locomotive carries the coal, coke, and water required during the journey. Besides these, the driver generally has with him two or three tools, in case of any trifling accident happening to the machinery, which he can thus repair.

The whistle of the locomotive is made on exactly the same principle as the common boy's whistle. It is, however, a round one, and the steam issues from a rim, and striking against a thin brass bell placed over it, produces the well-known sound.

In most locomotives all the wheels on each side are connected together by means of a long rod. The object of this is to prevent them slipping. When a train is about to start, the wheels of the engine sometimes slip on the rail, especially in wet weather. The arrangement we have named, together with a little sand which is let out of a small box in front of the wheels, are the two methods adopted to prevent this slipping.

The annexed engraving represents an improved kind of locomotive, such as is now generally employed. (See fig. 13.)

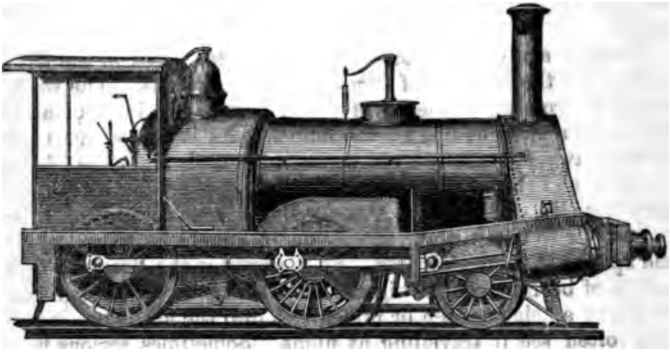


Fig. 13.

You will observe a covering at the end, where the driver is placed, and you will never know the value of such an arrangement until you spend an hour or two alongside of the driver. Even in fine weather the force of the wind as the train rushes on is very troublesome to a stranger; but when you add to this, hail, snow, rain, and dust, all of which are rushing on you at perhaps the rate of fifty miles per hour, you will at once see that travelling on an engine is not the most pleasant occupation in life.

As you will, perhaps, never have the chance of performing such a journey, we will give you the benefit of our own experience. In travelling at the ordinary speed on an engine, in a flat country, such as you find in Essex, Cambridgeshire, &c., the trip is, perhaps, as pleasant a one as you can choose, provided the day is fine. Our first attempt at a journey of this sort was on the Gravesend and Chatham line. About half-way between the towns you have to pass through a tunnel, in which, at the time we speak of, the road was built on piles over the water of a canal. The least slip on one side would have sent engine and all into the water. Looking straight ahead, nothing but pitchy darkness could be observed; and what with the noise of the train and its echo, together with the glare and smoke of the fire, we could only imagine that we had by some means gained an entrance to a Pandemonium. In travelling amongst the cuttings of a rocky country, such as that between Kendal and Carlisle, or between Edinburgh and Kelso, the effect on a stranger is peculiar. You *constantly* imagine at each curve that you will almost instantly run into the rock. The speed you are travelling at blinds the eyes and has a stupifying effect, from which you are suddenly roused by another train rushing past you, and leaving you in a mist of dirt, dust, steam, and smoke, emitted from its funnel. We never read of the trial of any unfortunate engine-driver, without heartily wishing that the jury were compelled to take an hour's trip on an engine, before they delivered their verdict. They would then be able to make a just allowance for the physical miseries which these poor fellows have to endure.

With respect to the utmost speed which can be obtained by a locomotive, there is, we believe, no reliable information. We have an indistinct remembrance of reading an account in a newspaper, some years ago, of a trip said to have been taken by Mr. Brunel and other gentlemen on the Great Western line; and if our memory serves rightly, they attained a speed of nearly one hundred miles per hour. We have often travelled between Slough and London, a distance of eighteen miles, in twenty minutes by the morning up-express. On one occasion, after we had been detained by an accident nearly two hours between Derby and London, the few passengers in the train at Rugby were put in one first-class carriage, which, with the engine, tender, and break-van, formed the train. The distance of eighty-two miles was travelled over in ninety minutes. In the year 1835 the mail-coaches travelling to Manchester took eighteen hours on the journey. At the present time you can travel from Glasgow to London, a distance of over four hundred miles, or more than double that of from Manchester to London, in ten hours and a half, or at the rate of about forty miles an hour, including all stoppages.

THE MARINE ENGINE.

We now proceed to speak of the kind of engines employed in steam-boats. These are almost always of the low-pressure kind, and have attached to the cylinder, by means of a pipe, a condenser, in which the steam is converted into water, and again pumped into the boiler.

We have already so frequently spoken, both in this and the section on Heat, of the condensation of steam, that it will only be required that we should give you an idea of what sort of an arrangement a condenser is, and for that purpose we refer you to the annexed engraving.

On the left hand is the condenser, which in most cases, as in our engraving, is surrounded with water. Towards the lower part is a pipe through which water passes—the quantity of which is regulated by a stopcock and handle. At the top of the condenser is a pipe which leads from the cylinder, and by this the steam reaches the condenser. On the right hand of the diagram you observe a pump: this performs two offices, viz., that of pumping the air from the condenser which enters with the water, and it also supplies the boiler with water by means of the pipe passing to the right-hand side of the cut. In the side of the condenser a barometer is fixed, whose upper end terminates inside the condenser, and by which the vacuum of the inside of that vessel is indicated. Of course the mercury never stands so high as that of the ordinary barometer, because the vacuum inside the condenser is much inferior to the barometrical one. It should range from twenty-five to twenty-seven inches, on an average.

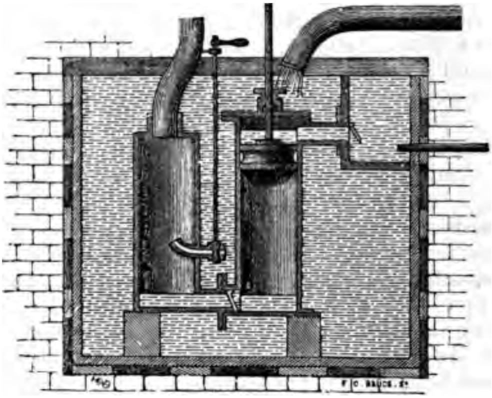
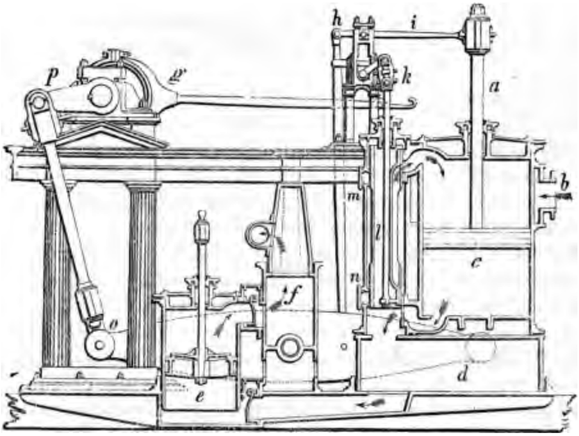


Fig. 14.

We need scarcely tell you that with a condensing-engine you can work with steam at a less pressure than that of the atmosphere. In fact, were you to open the safety-valve, the air would in such a case rush into the boiler instead of steam rushing out. In practice, however, this is never done. A pressure of from four to twenty pounds beyond that of the atmosphere is employed; and yet these engines are called "low pressure;" the term "condensing-engines" would be more proper, and is often used.

We feel some difficulty as to the choice of the best kind of marine engine as a subject of illustration. Like the stationary engine, they have assumed a vast variety of forms, both when used as screw or paddle engines. Fig. 15 represents a beam condensing-engine of the kind chiefly placed in large steam-vessels, and we add a description of each part.

Fig. 15.



In the above engraving we have a section of the beam, or, as it is sometimes called, the side lever engine, where

a is the piston rod.

b, the steam-pipe, leading from the boiler.

c, the cylinder, in which the piston works.

d, the beam, or side lever, to which the piston-rod is attached by means of a connecting-rod.

e, the air-pump, attached to the condenser.

f, the condenser.

g, the eccentric.

h and *i*, rods attached to the top of the piston-rod, which have the effect of keeping it in a straight position.

k, the rod attaching the eccentric to the slide-valve.

l, *m*, and *n*, the slide-valve and its box.

o, the cross-head by which the crank is connected by a rod with the beam or side lever.

p, the crank which turns round the paddle-wheels.

Messrs. Penn, of Greenwich, introduced a very useful form of the steam-engine, wherein the crank is fitted directly to the piston-rod. The cylinder oscillates to and fro; and hence these engines are called "oscillators." There are many of these employed on the Thames, and, with few exceptions, all the small steam-boats plying "above bridge" are fitted with engines of this class.

On the Clyde, an engine which has the crank over the top of the piston-rod, but not connected with it, is much employed; it has been called the "steeple engine," on account of its peculiar shape.

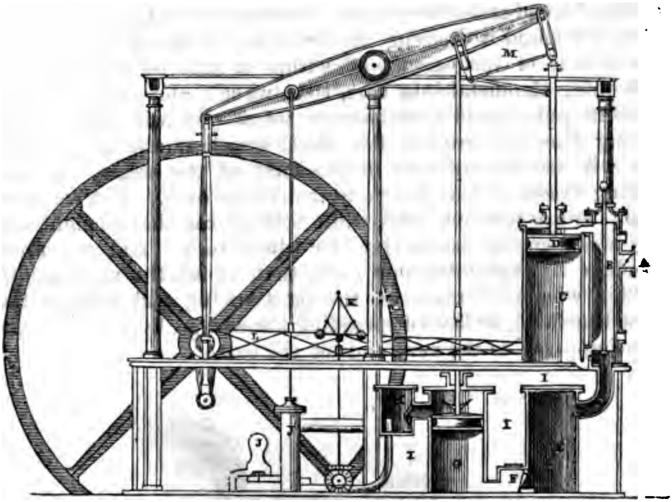
The engines employed in driving a screw steam-vessel are generally placed at the stern of the boat, and, whilst constructed on similar principles to those we have described, are made as compact as possible, for the purpose of economizing space.

The largest engines of either kind yet made are those of the "Great Eastern" steam-ship, which, perhaps, many of our young friends have seen. They are altogether an astonishing instance of human skill, and we could imagine the delight which James Watt would experience in witnessing the triumph of his inventive genius, as exhibited in the present day.

We have hitherto only mentioned the high-pressure engine as employed on land. In many situations where there is plenty of water, condensing-engines are used. It will be unnecessary for us to detain you by a long account of their construction: we have already spoken of each part, and shall, therefore, only furnish you with a description and engraving of one of the most improved kind at present used by millowners and others. (See fig. 16.)

In deep mines, for coal, iron, &c., a large quantity of water is generally found. This is a source of great danger to the miners, and therefore requires continually pumping away, to keep the mine in a fit state to work in. A peculiar kind of engine is erected for this purpose. A large cylinder is employed, as usual, but there is no fly-wheel or crank. The piston-rod is attached to the beam overhead, and at the further end of the beam long rods are connected with the pumps. On the steam being admitted into the cylinder, the piston is pressed down, and the water drawn up by the plunger of the pump. A few seconds of time are allowed, so as to permit the water to run away. Steam is then admitted to the lower part of the cylinder, and the piston again rises; the plunger of the pump descends; and thus the process of pumping is carried on. The boilers are often of a circular form; and as the cost of coal is very trifling, we need scarcely say that its economy in use is not much cared for,—a circumstance which makes the *neighbourhood* of a pumping-engine somewhat remarkable for the quantity of smoke emitted from the chimney. You will obtain a general idea of this class of engine, &c., by inspecting fig. 17.

Fig. 16.



In fig. 16 we have an illustration of the land-condensing engine, where
A is the throttle-valve of the steam-pipe.
B, the slide-valve.
C, the cylinder.
D, the piston.
E, the condenser.
F, a valve leading to the air-pump.
G, the air-pump.
H, a cistern of water supplied by a pump.
J L, the water-supply pump.
K, the governor.
L, a large cistern of water surrounding the condensers.
M, the rods for maintaining, by a parallel motion, the piston-rod in its proper position.

You will also recognise the beam-crank and fly-wheel, of which we have already spoken.

We have thus attempted to convey to your mind what we trust will prove useful information in respect to the construction of the high-pressure and condensing steam-engines. We omit further account of the expansive engine as being beyond the limits of our work.

With respect to the uses of the steam-engine, it would be impossible for us to give you an enumeration. It has been our good fortune to mix much with manufacturing and various other occupations. We have watched steam-engines spinning cotton, wool, and silk, and in the same city have seen small ones cutting bread-and-butter, and cleaning our shoes. In one place we found it drawing the treasures of iron and coal from the bowels of the earth, and within a mile off have seen it fashioning the metal into bars, rods, wheels, and steam-engines. In Birmingham and neighbouring towns you will find it producing pins, needles, and fine metal articles; and at Glasgow you will see it employed in the form of the steam hammer, forging masses of iron weighing many tons each. But we must stop: we are just reminded, while writing this, that a neighbouring steam-engine is waiting for the "copy," and we must conclude by expressing our belief that, of all the applications of this wonderful machine, the most useful, and perhaps the most beneficial, is that of spreading knowledge, by means of the printing-press, to the very ends of the earth.

Fig. 17.

WIND AND ATMOSPHERIC PHENOMENA.

In our previous pages of this section we have drawn your attention, in our experiments and remarks, to some of the most interesting laws and applications of the branch of science called Pneumatics. Before concluding the subject, we will say a few words respecting some natural occurrences.

In this country it is a common saying to observe of a person, that he is "as changeable as the wind," but science has lately thrown much light on the cause of wind, rain, &c. We have alluded to this when speaking of the barometer. Since the electric telegraph has been so much extended, philosophers have taken advantage of it to ascertain the changes of weather which are constantly occurring at places far distant from each other; and we need scarcely tell you that, residing in London or any other large town, you can in a few minutes learn the direction of the wind and character of the weather at almost any other place in Europe of which you choose to inquire.

Now, although the wind is changing continually, still it does so according to certain laws. The wind is caused by a current of hot air ascending from the earth, which, leaving a partial vacuum, causes the cold air to rush in to take its place.

If you should happen to travel in a hilly country, you will notice that there are always cold currents of air to be found at the tops of mountains. You may, in the north of Yorkshire, Westmoreland, and throughout the whole of the north of Scotland, observe, till about the end of May, that whilst in the valleys the air is oppressively hot, from the heating effects of the rays of the sun, the tops of the hills are covered with snow.

A few years ago, in the early part of June, we were enjoying a picnic party near Richmond, in Yorkshire, and the heat was extremely oppressive. Two of us, however, seeing some snow on a hill at a little distance off, determined to procure a little, and we were accordingly soon in possession of "iced wine." One side of the hills in such cases is very hot, and from these a current of air is continually ascending. Eventually the cold air at the top descends, and being heavier than the hot air, a brisk cold wind is produced. In extreme instances whirlwinds are produced by the same cause. In many parts of the Highlands of Scotland you will be suddenly surprised by a gust of cold wind, forming a pleasing contrast to the oppressive heat of a summer's day.

You will not fail to have noticed that when residing by the seaside there is almost always a pleasant breeze setting towards the land each evening. This is owing to the expansion of the air, caused by the heat absorbed by the surface of the earth, producing an ascending current. The air from the sea being cooler, blows towards the shore, to fill the partial vacuum created by the hot air.

Even in our churches and other places where large assemblies are found, the same rule holds good. The walls are cold, whilst the centre of the room is very hot. The hot air comes in contact with the cold walls, and being thereby cooled it rapidly descends, and all persons sitting near the wall will experience a cold draught. Some amusing results often take place owing to this; for whilst many persons are overcome with heat, others are shivering with cold in the same room. The glass of windows also has a tendency to produce these cold draughts, on account of its readily carrying away the heat from the air; hence in many places double windows are used, which generally correct this influence.

We once were consulted respecting the ventilation of a large church in London, where the causes we have named above were in full operation. It happened that there were numerous windows, and of course these rapidly cooled the air. Every attempt to warm the edifice on a winter's day was absolutely useless; for, whilst under such endeavours the *centre* of the church was far too hot, the *sides* were miserably cold. But the cure was remarkably simple: a sheet of thin calico, fastened over each window, prevented the hot air being rapidly cooled, and so, of course, stopped the downward draughts, of which so many complaints had been made. On the Sunday after the above simple remedy had been applied, the thermometer indicated nearly the same temperature at the sides and in the middle of the church.

We might easily extend these remarks, and explain to you the causes of a variety of other interesting occurrences in nature, such as hail, snow, &c., but this belongs more to the science of Meteorology. We trust that we have said enough to show you how universal the application of scientific truths is, for we have just seen that the storm of wind, the gentle breeze, and the ventilation and comfort of our houses, each depends on the existence of one law, and its action on one agent.

EXPERIMENTS IN HYDROSTATICS AND HYDRAULICS.

We shall now introduce a few experiments which will illustrate a branch of science called Hydrostatics; and here we shall have to refer chiefly to water, as a type of other fluids. We must here remind our young friends that, dealing as we are with the physical properties of fluids, their chemical characters will not affect the result of our experiments.

We stated in our Pneumatic experiments that the air had weight, and that it pressed with a force of fifteen pounds on every square inch exposed to its action. Fluids of all kinds exercise the same sort of pressure, and a very simple experiment will show that the greater the depth of the fluid, so much greater is the force with which it presses.

Experiment 1.—In the side of a water-butt or cask filled with water, bore three holes; one near the top, one in the middle, and one near the bottom. This can be done with a fine brad-awl, and the holes can afterwards easily be filled up with little pegs of wood. On observing the distance to which the water is projected, you will find that from the bottom hole to proceed farthest, because there the pressure is greater than in any other part of the cask.

A very singular result is obtained from the pressure of fluids: it is this, that a small quantity, say of water, can be made to balance a large quantity, as may be seen by the next experiment.

Experiment 2.—Attach to the tap of a cistern of water a gutta-percha tube, and then elevate the tube, in an upright position, so that it shall be parallel to the cistern. On opening the tap, the water will rush up the tube, and attain the same level therein as in the cistern; and if you now pour water into the tube, you will not be able to make it rise beyond the level of the water of the cistern, because they will just balance each other.

Experiment 3.—The effect of this may be better seen if you attach an upright pipe to a pair of common bellows. The weight of the air in the tube will not cause the bellows to rise; but if you pour in a little water, the upper part of the bellows will at once move upwards, owing to the pressure of the fluid in all directions.

Experiment 4.—Repeat the experiment, by first placing a heavy weight on the top of the bellows. Then pour in some water through the tube, and the bellows will at once rise. Instead of using a weight, you may stand on the bellows yourself.

Experiment 5.—These experiments succeed owing to the causes we have named above; and we can give you another illustration, showing you what an extraordinary effect a small portion of fluid may produce. For this purpose, fix into a small beer-cask a long narrow tin tube, so that the tube may reach inside, and fit in quite water-tight. Having all arranged, and presuming the tube is a few feet high, pour into it some water. Continuing to do so, the pressure of the fluid acting on all sides of the cask will be so great as to burst it.

On the same principle the hydraulic press is constructed. A small pump is connected with a large vessel in which a solid iron piston is accurately fitted. This piston rises up and down inside the vessel; and when in use, the small pump drives water into the large cylinder, and forces the piston upwards with enormous pressure. In this case a small quantity of water is *made to do* a large amount of work; and to give you some idea of the effect produced, we may say that if by means of the small pump you force in a column of water an inch wide, with a force of fifty pounds, and the area of the piston in the large vessel is 100 square inches, or say ten inches each way, you will thus get a pressing-force of no less than five thousand pounds, or something more than two tons. As, of course, the amount of pressure named above is very trifling, and as it is easy to work it with a pressure of much greater power, this instrument becomes of great value for a variety of purposes, for which a press may be required.

The Bramah press is much employed in the manufacturing districts, for compressing bales into a small space. As the rate of sea-carriage is charged on bulk and not on weight, this instrument becomes of great value, and diminishes the cost of

Fig. 1.

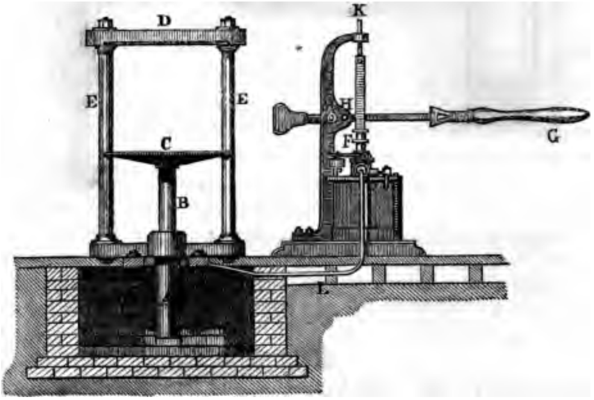


Fig. 1 represents the hydraulic press usually employed for the purpose we have named.

A is the press cylinder.
B, its plunger.
C, a plate on which the article to be pressed rests.
D, the top of the press, towards which C rises when the press is in action.
E E, two guides.
F, the pump cylinder.
G, the pump handle.
H, the fulcrum of the pump handle.
I, the plunger of the pump. (Fig. 2.)
K, the guide for the plunger rod.
L, the supply-pipe to the press, through which the water is driven by the small pump. (See fig. 2.)

carriage. Wool and cotton bales are thus pressed before being shipped to this country; and the extent of the pressure they have undergone may be judged by cutting one of the ropes with which such bales are bound. The rope will instantly burst open with great force; and if it should happen to strike the body, may do serious injury. A bale of cotton, after being unroped, &c., will soon expand to a space three or four times that of its previous bulk.

Fig. 2.

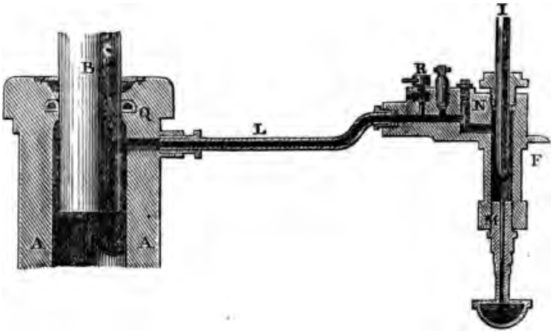


Fig. 2 shows a section of a pump and press.
M is a valve through which the water is pumped up.
N is a valve through which it passes to the press.
Q is a water-tight collar through which the press rises.
(The above letters refer to both diagrams.)

This press is often used for the purpose of raising weights. The Britannia Tubular Bridge was thus raised in sections. Enormous presses of the same kind were used in launching the "Great Eastern;" and a similar plan is often employed in our large docks, for the purpose of raising heavy weights from the holds of ships.

We can give you an idea of the extent of pressure which water exercises on any vessel in which it is resting. In our section on Pneumatics, we stated that a column of water thirty feet high balances a column of air forty-five miles high, or, in fact, is equal to a pressure of fifteen pounds; hence a pipe one inch in area, or about an inch and an eighth in the bore, and two feet long, will just hold one pound of water.

In Experiments 3 and 5, with the bellows or cask, it follows that if the tube you use is four feet high, it will contain two pounds of water; and, supposing that either bellows or cask contained a top surface of 100 square inches, you would obtain an upward pressure of 200 pounds; but as the pressure is equal in all directions, the whole of the surface of the cask would have to be measured in square inches, and the number so found to be multiplied by two pounds; when you would obtain the total pressure which the cask had to sustain before it burst.

It follows that, at great depths, the sea must exert a very great pressure on any substance in it. We have seen small pieces of wood which have been sunk to great depths, and which had been so compressed as to be heavier than water on being hauled up on deck. In sounding great depths at sea, and sinking with the lead a square corked bottle, the latter would have its sides crushed in by the immense pressure exerted by the water.

There is another property of all fluids to which we must invite your attention; and that is, their tendency to seek a level. The fact is so well known in daily life that you may perhaps be surprised that we should mention it; but as the applications of this law are so numerous, we must by no means omit it. The water-supply of our large towns is an instance of its application. In most cases a large reservoir is erected, from which pipes are laid. These pipes are called mains, and from them smaller ones are laid on, for the purpose of affording the supply to our houses. The water of the reservoir, running through these pipes, is simply seeking a level corresponding with that from which it has proceeded; and supposing the reservoir to be higher than the houses which are to be supplied, of course the water may be conducted to the highest rooms therein. You may illustrate this, and, at the same time, make a fountain in your garden, which will play as long as any water runs into it from a higher level.

Experiment 6.—Attach to a cistern, raised to some height, a pewter or gutta-percha tube, and to the end of this fix a stopcock and jet. If the latter are placed at a lower level than the cistern, the water, on being allowed to flow through the tube, will fly up into the air to a height nearly that of the cistern from which it flowed. It will not reach quite that height, because it has to overcome the friction of the pipe, and the resistance of the air. By placing such an arrangement in the centre of a flower-bed, you may easily construct a garden fountain.

The spirit level, used by surveyors, is made on the same principle. You may easily construct one as follows:—

Experiment 7.—Take a piece of glass tube, eight inches long and half an inch in the bore, and heat red-hot successively about an inch or two from either end. Draw each into a thin tube, and break off the end pieces. Now seal one of these, by holding its fine end in the gas flame till it is quite melted. When cool, put the tube into some hot water till all the air has been driven out except a bubble or two, and the water has taken its place. You must then seal the other end. If you place the level thus made on a table, you will find that if the table is quite smooth and level, the bubble of air will rest in the centre of the tube; if it is not, the bubble will rise towards that part which is highest.

The construction of canals depends on the principle that fluids will find their level. In almost every instance they are constructed at different levels throughout their length, and reservoirs called locks are employed to accommodate the levels to each other. On a barge requiring to pass from a high to a lower level, it is made to enter the lock. The communication between that and the upper part of the canal is then cut off, and the lock is gradually emptied of water until of the same level as the lower stream. The chief of the canals in England is the Grand Junction, which extends from London to Manchester. In Scotland there are two canals joining the Atlantic with the North Sea, on each of which you may often observe the strange sight of a full-rigged vessel sailing in a narrow stream through the fields and hills. We refer to the Forth and Clyde, and the Caledonian Canals.

A French engineer, M. de Lesseps, is at present engaged in constructing a canal across the Isthmus of Suez, which is intended to connect the Red Sea with the Mediterranean. When completed, it will be the largest of its kind. We need scarcely remind those of our young readers who are acquainted with geography that the passage of vessels through it will shorten, considerably, the voyage from here to India.

In hilly countries the principle of fluids always seeking a level has some very serious results. After a long winter, when either much rain or snow has fallen, immense bodies of water accumulate, and there collecting, eventually burst forth, spreading destruction on all sides. As this generally takes place very suddenly, the inhabitants of these districts have little warning, and a fearful injury to life and property thus occurs. About three years ago the Crinan Canal burst, and the force of water was so great that immense rocks were driven about as if they had been pebbles. The most remarkable instance of a sudden irruption of water from hills that we have heard of in this *country*, was one mentioned to us by a gentleman engaged in constructing a railway bridge over the Spey in the north of Scotland. A "wall" of water five feet high suddenly rose, and rushed on with such rapidity that a person who was mounted on a swift horse could barely reach the bridge in time to warn the workmen of the impending danger, the first intimation of it having been learned at a distance of three miles off.

The undulating appearance of many parts of England has been caused by the flowing of ancient seas in their search after a level. The daily tides which flow around our coasts are another natural instance of the operation of the same law. One of the most interesting instances, however, is that of well-digging, and more especially the construction of Artesian wells. In almost every part round and in London, water may be obtained by digging into the soil for a few feet. This is owing to the water from the surrounding hills sinking to obtain a level. Most of these hills are formed of sand, through which the water speedily filters, and pressing down with great force, it rushes rapidly up if the clay on which London chiefly stands is bored through. In some cases, the water thus obtained from Artesian wells rushes far above the level of the ground through which they have been bored, owing to its having come from a greater elevation.

FLOATING AND SWIMMING.

The next subject to which we shall allude in connexion with Hydrostatics, is that of floating bodies.

We must, however, refer to the remarks we made in a previous page respecting specific gravity; otherwise you will scarcely understand how it is that some bodies will float, and that others will not, in the same fluid.

We already have mentioned that specific gravity simply means the relation which bulk has to weight when two bodies are compared with each other. (See page 61.) But in the instance we there took, we assumed water as our standard, and as such it is generally employed. We must here, however, by means of a few experiments, extend your information on the subject.

Experiment 8.—Half fill a glass jar with cold water, and by means of a funnel, whose end just touches the surface of the water, pour some spirits of wine, which you have first coloured with a small piece of litmus. You will find that the spirit will float on the surface of the water, owing to its being lighter. The same will occur if any oil is poured on water.

You will thus see the necessity of having some definite standard with which bodies may be compared as regards their relative weights; and we shall now explain to you how these weights are arrived at.

EXPERIMENT 9.—Hang at the end of one of the pans of a pair of good scales, by means of a piece of silk, thread, or horse-hair, a piece of metal, as, for instance, lead. Now balance this exactly with weights in the other pan, after the usual manner. Take a note of this weight on a piece of paper. Having done this, dip the piece of lead into a glass of distilled water, and you will at once find that the pan from which the lead hangs will require some weights to balance it. By some means the lead seems to have lost weight. Now, this is owing to its having displaced water in the glass vessel equal to its bulk. In fact, if you try the experiment by using a glass *quite* full of water, you will find, on carefully weighing the water which runs over, allowing for waste, that the water will weigh exactly as much as the weight you must add to the scale-pan holding the lead to restore the balance.

If you now divide the amount which the lead weighed in the air by the amount you had to put into the scale-pan, holding the lead to re-balance the scales, you will have the specific gravity of the lead; or, in other words, you will learn how much more a piece of lead weighs than the same bulk of water.

Example.—Suppose the piece of lead weighed in the air forty-five grains, and that you required to put four grains into the scale-pan on the lead side. Divide 45, the weight in air, by 4, the weight lost, and you will have as the specific gravity of the lead 11.25, or a little more than eleven times that of the same bulk as distilled water.

You thus see how quickly difficulties in science may be got over by a little thought and perseverance. We recommend you to practise this plan of taking specific gravities by trying stones, pieces of metal, and other matters. Thus, whilst your information will be extended, you will also be attaining a readiness of manipulation, so necessary in scientific experiments.

EXPERIMENT 10.—If you want to find out the specific gravity of any liquid compared with water, fill a glass bottle with the liquid, having first ascertained how much the bottle weighed; then weigh the two. Having taken a note of this, now weigh the same vessel, filled with distilled water. Divide the weight of the liquid by that of the water, and the quotient will be its specific gravity.

The usual mode of taking the specific gravity of liquids is by means of the hydrometer, of which there are several sorts. A very ingenious contrivance of this class is that of a number of small glass balls, which vary in size, and are weighted so as to rise or fall in liquids which have to be tried. When they float in any part of the liquid, it shows that their specific gravity is the same as that of the fluid under trial. But the kind of hydrometer most usually employed is one consisting of two bulbs, to which is attached a long neck. The lower bulb is weighted by means of a little mercury; the upper bulb only contains air, and the long neck encloses a scale, on which is printed various figures relating to the specific gravities of liquids. Its mode of use is very simple. The liquid to be tried is poured into a tall glass jar; the hydrometer is introduced into it, and the figures level with the surface of the fluid are read off as the specific gravity.

We can mention another plan which can easily be carried out. Into a glass bottle pour as much distilled water as will weigh exactly one thousand grains, and make a scratch with a file on the outside, at the level of the fluid. Any other liquid of the same bulk will indicate, by its weight, its relative specific gravity to water on being weighed in the same vessel.

Having thus endeavoured to show you how to take the specific gravity of either solids or liquids, we shall now suggest a few experiments illustrating the reason why some bodies float; and shall also say a few words on the art of swimming.

To those who are unacquainted with the facts about specific gravities to which we have just referred, it would, at first sight, appear strange that iron and other metals may be easily made to swim or float on water. Indeed, when iron vessels were first introduced into steam navigation, there was a great outcry raised, on the ground of the great danger which would ensue in their use.

Vessels of any material float on water simply because they weigh less than their own bulk of that fluid. Thus, a vessel lightly loaded has its keel or lower part much nearer the surface of the water than one carrying a heavy cargo. This you can easily observe by watching a vessel whilst in course of loading. You will find a line painted round the sides of most vessels, called the water-line; and as the load is being put on board, the vessel sinks deeper into the water. In fact, her specific gravity is gradually increased. Vessels are never loaded so as to sink beneath this line in the water; and attention to this point is essential to the safety of the vessel.

If a boat is loaded to such an extent in sea-water that she just floats, she will certainly sink on arriving in a river of fresh water, because the latter has less specific gravity than salt water. The reason of this you may see by repeating the following experiments:—

EXPERIMENT 11.—Put a bottle, capable of holding about a quarter of a pint of water, into the scale-pan, and weigh it. Then pour into it exactly one thousand grains of distilled water, and make a mark on the outside of the glass, by means of a file. Throw out the distilled water and pour in some sea-water, so as to fill the bottle up to the scratch you have made on the glass. Now weigh the sea-water, and you will find that it will require about twenty-seven grains more to balance it; or, in other words, its specific gravity to pure water is as 1027 to 1000.

Hence, a vessel sailing from a river port will rise out of the water on getting to sea; and if you try the experiment on your body, you will find that you will be higher out of the water in the sea than in a pond or river.

The following experiments will impress this interesting fact on your mind:—

EXPERIMENT 12.—Float a piece of wood of an oblong shape, or a model of a ship, on some distilled water, and very carefully mark the water-line by means of a pencil all around its sides. Whilst in the water, press it down, and notice how soon it regains a still position.

EXPERIMENT 13. — Instead of distilled water use common river water. You will find that the vessel will swim higher, owing to the river water containing various impurities.

EXPERIMENT 14.—Make a strong solution of common salt in cold water, and now float your vessel in this. You will find that the water-line is very much higher from the level of the solution than in the last experiment. In fact, to use a common phrase, it is more buoyant. If you press the vessel down into the salt solution, you will find that it takes a longer time to come to rest than it would in pure or river water, for the same reason that it floats higher.

Ballast is used on board ships for the purpose of keeping them in an upright position when sailing; and a vessel without cargo will require more ballast when sailing out at sea than when in a river.

EXPERIMENT 15.—Place a piece of iron on a little mercury: you will find that it will float easily on its surface, owing to the great specific gravity of the mercury. If you have the opportunity of experimenting with a large quantity of mercury in a basin, try and force your hand to the bottom, and you will find considerable difficulty in so doing.

By bearing these facts in mind whilst you are learning to swim, you will feel the necessity of keeping the chest as full of air as possible, because that will diminish the specific gravity of your body, which in ordinary cases is much the same as that of river water.

SWIMMING.

The great difficulty which young persons have in learning to swim is to gain confidence in the fact that they cannot sink unless they make up their minds to do so. Now, this seems very strange, and apparently contrary to the truth; but we think we shall convince you, if you determine to try the following experiments. We may just say beforehand that in one or two rivers in Great Britain—the Lea, near London, and the Clyde, near Glasgow,—the water is very soft, and free from salts, &c., so that as far as our experience goes, they offer more difficulties to the learner than any other. The reason of this you will remember by referring to our experiments with the vessel. (See Experiments 12, 13, and 14.)

EXPERIMENT 16.—Choose a pond, or other sheet of water, which is not deeper than to allow you to stand up to within a few inches of the armpits in it, and drop a large stone, so that it may fall close to your feet. As it is passing through the water, observe how slowly it sinks, and remember, at the same time, that it weighs two-and-a-half times the weight of the same bulk of your body. Put out one of the feet, to catch it, and observe how very slight the blow is with which it strikes the foot.

EXPERIMENT 17.—When the stone is at the bottom, fill your chest with air, close your mouth, and dip the head and arms into the water. You will find considerable difficulty in getting them down to any depth, because your lungs and arms weigh so much less than their bulk of water.

EXPERIMENT 18.—Now try and pick up the stone; and we think that before you succeed, you will be completely convinced that it is a vast deal more difficult to sink than to swim.

Divers are aware of this; and, for the purpose of causing themselves to sink, they often hang weights to their bodies. In all cases they are obliged, if without weights, to take a plunge head foremost; and even then they cannot go very deep into the water. To give you an instance of this, we may state that being by no means the best form of body for swimming, and also of more than the average height, we have never been able to go deeper, in plunging from a bank two feet higher than the water, than about a couple of feet beneath the surface.

Having thus convinced yourself of the *difficulty* of sinking, you may take the next step — of learning to float. Many persons recommend the use of bladders and cork floats; but we would urge you *not* to adopt them. They are only intended to give you confidence in the water; and we earnestly hope that the experiments we have suggested will have had that tendency. In fact, bladders are positively dangerous. We once saw a young man nearly lost through trusting to a pair of these placed under his arms. By some means, one bladder burst, and, having foolishly trusted himself out of his depth, he was rescued with considerable difficulty.

Experiment 19.—*To learn to Float.*—Whilst standing in a shallow place gently fall backwards in the water, throwing the head back as far as possible, taking care to keep the mouth out of the water. ☞ *All other parts of the body should be kept below the surface, as far as possible.* They thus assist to float the head—which is one of the heaviest parts. You will find, if you try this in a calm manner, that the arms and legs are so light that they will gradually rise to the surface.

Experiment 20.—If you have a friend with you, ask him to place the palm of his hand at the back of your chest. You will find that the least pressure, on his part, against your body, will easily raise you up; and you will thus gather an additional amount of confidence.

Experiment 21.—When you can thus float without any fear, keep the palms of the hands turned downwards, and press them gently against the water; you will find that you can easily raise yourself thus. Afterwards, bring the feet in towards the body, and then drive the soles flat against the water. You will observe, that if in still water, you can thus push yourself onwards. Repeat these motions until you "learn the use of your hands and feet"—one of the chief arts in trying to swim.

From floating you may proceed to swim forwards; and for this purpose the head must be inclined backwards, as before; but we shall not pursue the subject further, as our plan is simply to teach the scientific truths involved in swimming, and not the entire art.

We may, however, very properly give you the following cautions, each of which is suggested by a knowledge of scientific laws:—

1. Never enter the water when you are cold. Fear and cold *contract* the body, and hence *increase* its specific gravity.

2. Always keep the chest as full of air as possible, because that *decreases* its specific gravity.

And lastly, remain in the water only so long as you feel a healthy glow. On the first feeling of fatigue, quit it immediately.

In diving you must remember our remarks on carbonic acid in our Chemical section. As a continuous supply of oxygen is required, no person can remain long under water. Fishes are enabled to do this because they gather oxygen from the air which the water contains, by means of their gills. Hence, a fish cannot live in water from which the air has been extracted by means of the air-pump.

In case of accidentally falling into the water and being unable to swim, you may easily keep on the surface by floating on your back, as we have just directed, or, if your hat should be close to you, instantly turn it, with the open part downwards. From its being full of air you will float some time, if you hold it by both hands in front of the chest. For this reason ladies' dresses, which enclose much air, from their expanded form, have often been the means of saving their lives in similar circumstances.

WATER ENGINES.

We shall now introduce a few illustrations of some different means of employing water for the purposes of a motive power; and although our descriptions will not afford many experiments, you will be able to learn the *modus operandi* of matters you may meet with in your walks and country visits. In our humble opinion, nothing exhibits to better advantage the intelligence of young persons than their ability to explain the why and wherefore of various arrangements they may accidentally examine. Sometimes, indeed, their future prospects in life may be influenced thereby. We shall relate an instance, being that of a gentleman well known in England, and whose acquaintance we have enjoyed for many years. Several years ago a poor boy was engaged as errand lad in a large warehouse in ——. After being there for a short time, he accidentally discovered an error in a calculation which one of the clerks had made, by looking over a piece of paper which he was sweeping out of the counting-house. After much hesitation he determined to inform his master, whose interests were compromised to the extent of nearly a thousand pounds. His employer was so pleased with the intelligence the youth had shown, that he immediately advanced him; and, to cut our story short, we may state, that he prospered so well as to have been chosen member of Parliament for one of the largest cities in the empire, and during the late session took a very active part in connexion with public affairs. We hope some of our young friends may go and prosper likewise.

Experiment 22.—One of the simplest modes of removing water from one vessel to another is that of using the syphon. This is a pipe bent in the centre, so that one leg shall be longer than the other. You can easily make one, by bending a piece of pewter tube, say two feet long and a quarter of an inch wide, until one leg shall exceed the other by two or three inches, and be of the shape of the letter U.

Experiment 23.—Place the shorter leg in a basin of water, and draw out the air by the mouth from the longer leg. The water will flow out of the basin through the pipe, until the whole of it has passed away. This is owing to the water in the shorter not balancing that in the longer leg; and as that from the shorter one rises, the pressure of the air acts on the liquid in the basin, and forces the whole of it over.

Experiment 24.—Let the long leg of the syphon rest in another empty basin. When sufficient water has run over to fill both vessels to the same depth, the action of the syphon will cease, because both legs are then in such a position as if they were of the same length.

Experiment 25.—Now lower the basin containing the end of the long leg. You will find that the water will at once commence to run over again. You will thus see how it is that the syphon works. Those which you often observe used in the streets by men removing spirits from casks, act in exactly the same way. They have simply the addition of a small tube at the side, by which the air is withdrawn, the person placing his hand at the same moment over the end of the long leg of the syphon, or closing it by means of a stopcock.

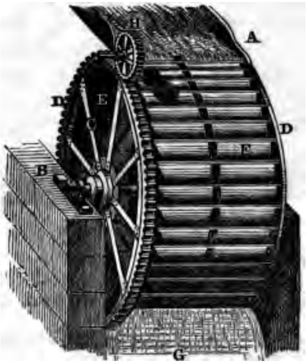
A very amusing toy is sold by the philosophical instrument makers, called a Tantalus cup. In the lower part of the figure a syphon is concealed. The glass is filled with liquid, and so long as it rests upright the liquid remains in the glass; but on tilting it on one side the syphon begins to act as named in Experiment 22, and the liquid runs into a lower vessel, of course disappointing the drinker.

Our classical young friends will remember the fable of Tantalus, who for some misconduct was placed by Jupiter in *a river*, whose waters flowed away from his mouth when he attempted to drink. Hence the name of the toy we have described.

Experiment 26.—The next simple instrument to which we shall call your attention is the water-hammer. It is a long glass tube, at each end of which is a bulb. One of these can be made by having two bulbs blown on a glass pipe by a glass-blower, one of which must be sealed. Some water is introduced into the sealed bulb, and boiled until the steam has driven out all the air. The other bulb must then be instantly sealed, and on allowing it to cool, you will find that as the water falls from one end to the other a loud noise is produced, which would lead to the impression that some solid body was contained inside the vessel. This effect is due to the resistance of the air having been removed, and thus the water in falling is enabled to acquire considerable impetus or force before striking the glass bulb.

That water when flowing has considerable force, is evident if you watch the effect of the tides as they rise and fall in a river. Even the ordinary current of a small stream may be employed for the purpose of obtaining a motive power. Hence the invention of water-wheels, such as are employed in various parts of

Fig. 3.



AN OVERSHOT WHEEL.

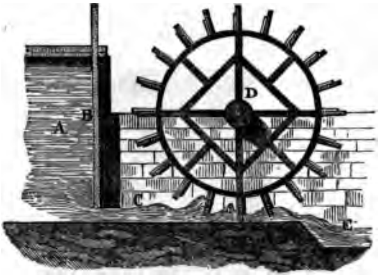
A is the spout supplying the water.
B, the shaft of the sheet to which the machinery is sometimes attached.
C, the spokes of the wheel.
D, a tooth-wheel which connects with other wheels, and so moves the machinery of the mill.
E, the plate on which the buckets are fastened.
F, the buckets which receive the water from the spout, A.
G, the water running away from the wheel.

the country for use in flour, spinning, and paper mills. These are chiefly of three kinds, namely, the overshot, undershot, and breast wheel; and, of course, they can only be employed in such places where an abundant stream of water can be obtained.

The *overshot* wheel is so called because the water runs from the stream on its upper surface. The water is brought to it by means of a long trough, which ends a little past the top of the wheel in a kind of spout. In this wheel the *weight* of the water is the moving power to a large extent. Fig. 3 represents one.

Our next engraving illustrates the *undershot* wheel, in which the water is supplied at the bottom, and acts by its impetus or force against the floats of the wheel. This kind of water-mill is in most respects of the same appearance as the paddles of a steamer. To work this and the next kind of wheel a long canal is generally made, which collects the water from a distance and from a higher level. The water is retained in this canal, or as it is termed a mill-race, until required for use, by means of a gate called a sluice.

Fig. 4.



AN UNDERSHOT WHEEL.

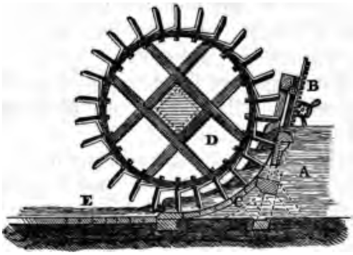
A is the reservoir of water.
B, sluice, or gate, by which its supply is regulated.
C, the channel in which the water runs from the sluice against the floats of the wheel.
D, the wheel, with its floats, which are boards fixed on its spokes.
E is what is called the tail-race, in which the water rapidly passes off.

The *breast* wheel obtains its name from the water being supplied at the side of the wheel, a little below a line drawn from its centre, and the letters in our next figure have the same indication as in the last, except that C points out the course which the water takes in driving the wheel. (See fig. 5.)

In these you have illustrations of the chief of the different kinds of water-wheels employed in our own country. In

Egypt and other places various other sorts are used, to which our limited space will not permit us to allude. You can very easily have models of these wheels made by an intelligent tinsmith, and at a very slight cost; and by an ingenious contrivance of the syphon, which we described in our Experiment 22, you can work small models without any difficulty. A pretty set of these was presented to the London Polytechnic some years ago, and they excite much curiosity and amusement amongst the juvenile visitors of that useful institution.

Fig. 5.



A BREAST WHEEL.

Water-Clocks.—Nothing is more easy than to construct an arrangement which, by the regular flow of water from a pipe, may be made to show something near the time of the day. In former days these were the only means employed for that purpose, and were sometimes of very complicated construction. Sand-glasses were used for the same purpose, and in some of our old churches you may still see the old hour-glasses. There are very few old churchyards in England and Scotland wherein you may not see an hour-glass cut out on the tombstones.

Experiment 27.—*To make a Water-Clock.*—Paste on the outside of a tall glass jar a strip of paper, and having made a syphon (see Experiment 22) of a very small bore, fill the glass with water and set the syphon to draw off the liquid, as we have already described. At each hour, half-hour, and quarter, make a pencil-mark at the exact spot where the water-edge is formed, of course using a clock or watch for the purpose of ascertaining the time. These marks will at once indicate how much water has passed out of the glass vessel in a given time. You will have to fill up the glass jar whenever the water has nearly run out, just as you would have to wind up a clock. You should also place a sheet of paper on the top of the jar, to prevent loss of water by evaporation.

The above is undoubtedly a clumsy mode of measuring time; but after all it may be made quite as accurate in its indications as some of the cheap watches we often see exposed, and which are, generally speaking, only made to "sell."

By means of wheels like clock-work, a water-clock may be made to register time on the face of a dial, and so really to form an efficient clock; but the arrangement would be too complicated for you to attempt to make one.

Rain-gauges are employed for the purpose of registering the amount of rain which falls, say in an hour or day; you can easily construct one as follows:—

EXPERIMENT 28.—*To construct and use a Rain-gauge.*—Into the top of a tall glass jar fit a tin or zinc funnel. The jar may be a foot or eighteen inches high, and an inch and one-eighth wide. The funnel should be ten inches square at its upper rim. On the outside of the glass jar fasten a strip of thick paper. This you must do by means of a solution of shell-lac instead of paste, because the rain would otherwise soon wash it off. This paper must be divided into inches and parts of an inch, in the following manner:—Suppose that your funnel measures ten inches square, it will have an area of 100 square inches. If your glass is an inch and one-sixteenth in diameter, its area will be one square inch; hence every inch in height in your glass jar will correspond to one-tenth of an inch of rain-fall. Make, therefore, plain marks at each inch of height on the strip of paper, by means of a *pencil*, and then varnish it over with some of the shell-lac varnish with which you fastened it on the glass jar.

We have given a diameter a little too large for the glass jar, but still near enough for your purpose. If you place this gauge in any position on the ground, where it shall be quite exposed to the sky, but not too much affected by the wind, you will be able to measure the daily fall of rain; and may add the result to your memoranda of the weather which we recommended you to make, when speaking of the barometer. Remember that each inch of your glass jar shows a fall of only a *tenth part* of an inch. You should examine the gauge each morning, say at nine o'clock; and having noted down its contents in your "weather" book, empty the gauge, and leave it till the next day at the same hour.

To stimulate you in such interesting observations we may tell you, that if you make these in a careful and systematic manner, you will not only have a constant object of interest before you, but may largely add to the stock of useful information; especially if you live at some distance from a place where an observatory is stationed. If you will take the trouble once a week or month to copy your results on a large sheet of paper, *written on one side only*, and send them by post to the Secretary of the Meteorological Society, London, such will, we are sure, be most thankfully received.

We have some young friends who not only interest themselves in such matters, but actually make a considerable profit by collecting insects, plants, sea-weeds, minerals, and geological specimens, and disposing of them to collectors of these objects, and museums in large towns of England and Scotland. Although we may pursue science for its own sake, still there is no reason why we should not profit by it. The late celebrated Hugh Miller had collected a large geological museum whilst following his occupation of a stone-mason; and we are sure that many of our young readers will have far better opportunities of collecting such matters than had that eminently hard-working man. Remember the old proverb, "*Nil sine labore*," or as Poor Richard says—

> "There are no gains without pains."

We shall next refer to some singular methods sometimes employed for raising water, and of some of these you can easily make working models.

One of the last objects that you would suppose capable of suggesting an invention, would be the tongue of the common cat. You will no doubt have often watched her lapping up her milk. If you were to try to follow her example in drinking you would not succeed, because your tongue was intended for a very different purpose, and is differently constructed.

Some years ago an inventor proposed to draw out water from deep mines by having a long and endless web of strong cloth stretched round two rollers, one of which was to be placed at the bottom of a mine, and the other at the top,—just, in fact, like the pulleys and bands by means of which machinery is driven. The top roller was to be driven at great speed, by means of a steam-engine, and then the band was run up and down the mine. The lower roller was placed beneath the level of the water at the bottom of the mine, and as the cloth band rose some of the water adhered to its surface, just as the milk sticks to the surface of the cat's tongue.

The water may thus be carried to almost any height, and at the top of the mine a kind of scraper is fixed, which tears the water off, and so allows the web to return to the mine comparatively dry. One of these was erected in the London Polytechnic some years ago, and we have seen it drawing up water to the height of thirty feet with perfect ease.

EXPERIMENT 29.—You can easily construct a small model of one of these machines. For this purpose fix an iron peg, four inches long, at each end of a board. On these place two wooden rollers, such as common sewing-reels, but larger, so that they may easily turn round on the iron pins, and fix a handle into one of them. You must now sew together the two ends of a piece of thick calico, which shall be just long enough to stretch over both rollers, and form an endless band round them, two inches wide, just in the same way as cord is fitted round the rollers of window blinds. If you place one roller in a pail of water, and turn the handle of the other roller, so that it may wind the web round both, and hold your model upright, you will find the water "licked up," just as we have stated is done by the machine above described. The faster you turn the handle, the more liquid will be raised.

To still further understand the principle on which this works, watch the hind wheels of a cart and a cab, when running in a wet road. The former will raise only a little water from the ground, but the latter, presuming that it is going at some speed, will raise the water two or three feet, and, unless you keep a respectful distance off, may put an unpleasant end to your philosophical studies by casting the water over you.

Another very ingenious mode of raising a liquid is that of the water-ram, the principle of which we shall explain to you before we speak of its construction.

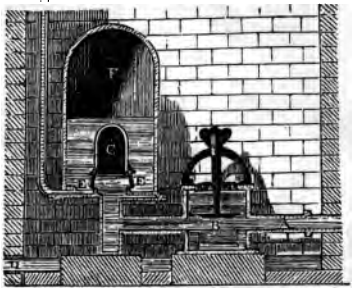
EXPERIMENT 30.—Bend a glass tube in a gas flame till it is of the shape of the letter L. The upright leg may be two feet long, and the horizontal or bottom one about four inches; or you may perhaps make the tube of this form more easily by bending a piece of pewter pipe, and fitting a straight glass one into one end, so as to make it of the shape we have mentioned. Place the short leg in a stream of running water, so that its open part may face the current. You will find that the water will rise much above the level of the stream in the long tube, and the faster the current the higher will the liquid rise.

A gauge of this sort can be fastened at the bows of a boat, or other vessel, and by graduating the tube the speed will be at once shown.

On the above-explained principles the hydraulic ram is constructed, an excellent form of which we have represented in fig. 6, in which the water flows from a reservoir through A, into an air vessel, F, from which a portion of the water is driven *upwards* through the narrow pipe on the left of the engraving.

Its momentum is increased by the action of valves, which make the effect that of a number of shocks on the water.

Fig. 6.



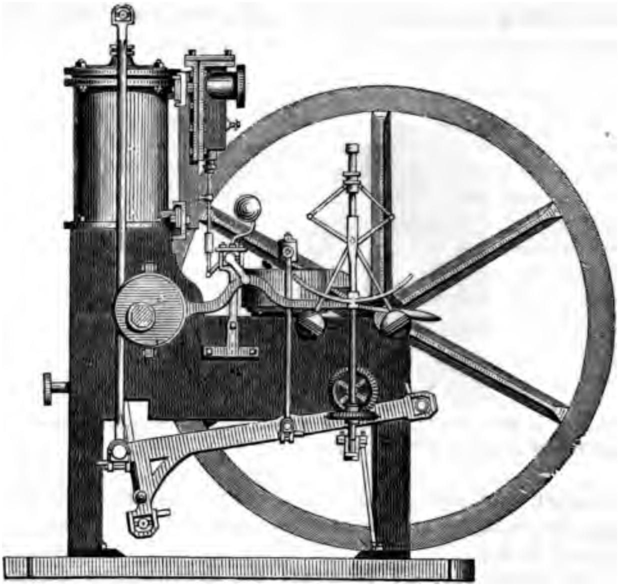
A is the supply; B and E E are valves; C and F, air-vessels; and D, a waste-pipe.

Another, and also highly ingenious plan, is that of Archimedes, hence called an Archimedean screw, one of which you can easily make.

EXPERIMENT 31.—*To construct an Archimedean Screw.*—Wind round a roller of wood, a foot long and two inches thick, a length of pewter tubing, say of a quarter of an inch in the bore. It should be wound in the same way as you will observe in the common screw, with each thread of the screw about an inch apart. If you now place this *slantways* in a pail of water, and turn the roller round quickly, the water will gradually rise in the tube, and may thus be lifted out of the pail.

There are numerous other modes of raising water, which are very interesting. We have, however, selected those of which you can easily construct models, and shall, therefore, not weary you with adducing any others.

You will not fail to observe how numerous are the applications for which water may be employed. One of the great advantages of the study of science is, that it always tends to relieve man of the employment of what is sometimes called brute force; and just in proportion as this point is reached, so we set free his intelligence. That which used to be effected by *hand* work is now done by *head* work; and although some of our young friends may think it is the harder of the two, they must remember that is the most suitable to call out the faculties of a rational being.



HENRY BELL'S STEAM-ENGINE.

MECHANICAL EXPERIMENTS.

YOUNG persons generally suppose that the branch of science called Mechanics is one of the most uninteresting of all. It is so if it is studied by those who have not had a thorough mathematical training, but to such it becomes a source of deep interest. We are, however, inclined to believe that there is plenty of room for amusement even on this "dry" subject, and if our young friends will permit us, we shall endeavour to prove our position. In doing so, however, we shall make the title of this section of a very wide signification, yet, we trust, without doing violence to sound scientific arrangement.

In our Chemical section we considered the different qualities of bodies; under Heat, &c., we experimented with those forces which change the appearance and nature of things; under Sound and Pneumatics we spoke of certain laws which gases *obey;* and in our last section, fluids, such as water, were the objects of our experiments. We shall now deal with solids, and give you some experiments on various laws to which they are specially subject.

You will at once admit that no two *solid* bodies can occupy the same place at the same time, but we do not always admit the same truth as regards liquids. Thus, when we dip the hand into a glass of water, we do not seem to force the water away from the hand, because it does not seem solid; the following experiment, however, will at once correct our ideas.

EXPERIMENT 1.—Pour some powdered lycopodium on a basin of water, and afterwards dip in the hand. You may do so without wetting it, for on withdrawing the hand no water will adhere to its surface.

In the same way, if you drive a penknife into wood, you simply drive on one side the small parts called atoms, of which the wood is composed. The only difference between the wood and the water in a mechanical point of view is, that the parts of the wood lie closer together. The property of matter of which we are now speaking is called its "impenetrability."

If you inquire how it is that bodies are solid, we answer, that they are held together by what is called cohesive attraction; that is, their parts are more closely together than those of liquids or gases, in which heat keeps their parts more distant from each other. The following are curious illustrations of this power:—

EXPERIMENT 2.—Cut a lead bullet in half, and immediately place the two halves in contact with each other. If you now give them a slight turn, pressing on them at the same moment, they will again adhere.

EXPERIMENT 3.—Press together two highly polished and clean pieces of plate-glass. They will, generally speaking, adhere with great force. For this reason the plate-glass companies always send out the glass with pieces of paper between each plate, to prevent their adhering to each other. But this power of adhesion or cohesion varies very much in different substances, as the following experiments will show:—

EXPERIMENT 4.—Lift up a heavy weight by means of a cord, a zinc, a lead, and an iron wire. Supposing that they are each of the same thickness, the cord, zinc, and lead wires will not sustain anything like the weight which the iron wire will do; hence we learn that the cohesive power of the iron wire is the greatest.

EXPERIMENT 5.—We can name a curious experiment with a cord, partly depending on its cohesion. Hang a heavy weight to the end of a *very dry* piece of rope, so that the weight shall just touch the ground. Now wet the cord thoroughly, or leave it all night in the open air during damp weather. In either case you will find that the parts of the cord have drawn nearer to each other, and so making the rope shorter will raise the weight from the ground.

Experiment 6.—Cut a piece of common india-rubber, by means of a clean penknife, and then bring the edges again into contact; they will instantly adhere, owing to their cohesive power. By similar means india-rubber tubes may be made.

Experiment 7.—Cut a piece of sheet india-rubber into slips, half an inch wide, and wrap them evenly round a pencil, so that their edges may come in contact. Press the edges well together, and leave them thus for a short time. You will see that they will adhere so closely as to make one piece; and if you remove this from the pencil, you will find that you have obtained a complete tube.

Experiment 8.—Rub the edges of the india-rubber with some powder, of almost any sort. You will find that you will not be able to make the edges to adhere now, because of the presence of the powder, which prevents them coming close enough for the attraction of cohesion to exert its power.

Air and many bodies exert the same effect. You will remember our experiment with the "sucker," under the head of Pneumatics, which, after the air was removed between it and the stone, adhered to the surface of the latter with great force. If it were not for this separating or repulsive power which such substances have, a great many inconveniences would arise in our daily life. For instance, we should never be able to leave hold of a friend on shaking hands with him. If we sat down on any seat there we should have to remain. Indeed, if we actually come in contact with anything, we should either take from them or leave a portion of ourselves; and it is by no means an exaggeration if we tell you that one of the rarest things you do is to touch anything solid, although you seem to be doing so every moment of your lives. If you place your finger on polished plate glass, there is between it and the finger a stratum of air, grease, and water. If, however, you extend your experiment, and try a red-hot piece, you will be more successful, and most likely to your sorrow.

It will be needless for us to multiply instances of this kind; they are so common in daily life as to be found in every moment of our existence.

There is another property of all bodies, which is called "inertia." That is, no body can set itself in motion, nor when [illegible]ce started will it ever stop, unless some opposing power causes it so to do. You will at once say that this is quite contrary to your experience, but we will soon convince you of its truth. Take, for instance, the case of the cannon ball. It would not move of itself, but when driven forward by the gunpowder it eventually falls to the ground, and there rests. This is owing to two causes; one being the attraction which the earth has for it, and the other, the resistance of the air. To learn the extent of the latter, you can try the following experiment.

EXPERIMENT 9.—Procure a sheet of tin-plate and a leaden ball, each weighing the same. To each of the four corners of the plate hang a string, and tying the four strings together, attach a stone to them, so as with the plate to form a kind of parachute. Drop this with the stone downwards and the leaden ball, both at the same instant, from a window near the top of a house. You will find that although the plate, &c., weighs the heaviest, it will take a longer time to reach the ground than the ball does; because, exposing so much more surface, the air affords a greater resistance to it.

For the same reason, cannon shot and rifle bullets are made of a pointed shape, the bows of a vessel are made sharper than the stern, the edge of a knife finer than its back, &c.

In each of these instances you will perceive that there is some cause which brings the body to rest. We shall now refer to another, which is made much use of or avoided in most machines, we mean that of friction.

EXPERIMENT 10.—Place a piece of unplaned wood on a rough board, and raise one end of the board, so as to form an angle with the ground. You will find that the friction of the two pieces of wood is so great as to prevent the smaller one running down the board.

EXPERIMENT 11.—Now plane both surfaces, and afterwards grease them with a little lard. You will observe that they will then move more easily over each other's surface, because the friction is diminished.

The following are instances wherein friction is lessened by similar means, as in the launching of ships, when the "way" is greased, the oiling of axles and spindles of machinery and the axles of cart and carriage wheels, &c. A national misfortune arose to us only three years ago, in India, through this piece of science being put into practice. It was found that if the cartridge of a common rifle is greased the ball flies truer to its mark. But as the use of grease of an animal kind is forbidden to the Sepoys by their religion, their rebellion is stated to have been caused by their being compelled to employ it for the purpose we have named.

Of so great consequence is the lessening of friction in machinery, that its neglect in large mills may cause the most serious accidents. We were some years ago standing in front of a large spinning frame, and watched the whole of the solid iron framework, two inches thick, completely drawn up. This caused a loss to the owner of above one hundred pounds, whilst the value of the oil which should have been applied would not have been a penny. You will say that this was a case of "Penny wise and Pound foolish."

A very well-known effect of friction in destroying bodies is met with in the operation of sharpening knives. The heat produced is so great as to burn off particles of the steel. Sometimes, owing to the friction of the axles of railway carriages, the train is set on fire; and if several axles were to become heated in the same manner, the train would be stopped by their friction.

Friction is employed for the purpose of lessening motion; railway and other brakes are instances of this.

Those of our young friends who are fond of skating and sliding know the value of smooth ice for that purpose. In many parts of the North of Europe skating and sleighing are more commonly adopted than travelling in carriages to which wheels are attached.

Wheels are a contrivance intended to diminish friction, and the following experiment may be tried to illustrate their value.

EXPERIMENT 12.—Supposing that you are desirous of removing a heavy weight much beyond your power, raise one end, by means of a crow-bar, and place under it a small roller of wood or iron; you will now be able to push it a short distance. Continue placing rollers until the whole bulk rests on them; you will then be enabled to remove a very heavy weight with great ease, owing to the reduction of friction which the use of the rollers has effected.

Blocks of stone, logs of mahogany, &c., are thus removed from the places where they are obtained. In America they use rollers for a very extraordinary purpose. Whole houses are sometimes moved from one street to another, without at all disturbing the furniture, &c. Some years ago, the same plan was adopted to remove a lighthouse in the north of England, which was carried by rollers to a considerable distance, without sustaining any injury, and at last was safely deposited in its new position.

In Experiment 12 we mentioned the use of a crow-bar, and this leads us to say a few words about levers.

The simplest instance we can offer you of a lever, is that of the common poker. When you stir the fire, you take care to have the shortest part of the poker distant from the bars, on which you rest it, in the fire, and the end of the longest part in your hand. Different names have been given to these parts of a lever; they are these: the part where the poker is held in the hand is that where the power is applied; that which is in the fire is where the resistance is overcome; and that which supports the poker, someway between these two points, is called the *fulcrum*. When stirring the fire, the fulcrum is the grate-bar on which the poker rests.

The crowbar, the hand-spike, the end of the hammer used for drawing nails out of wood, a pair of scissors, &c., are all instances of levers of this kind. In every instance, you will find that the further the point at which you apply the power is from the fulcrum, the more force you can exert on any resistance.

The beam of a pair of scales is an instance of a lever of this kind, and we will here suggest an experiment, by which you can have some fun with those who do not understand anything about levers.

EXPERIMENT 13.—When being weighed in a pair of scales with the beam overhead, request the person to weigh you very exactly. When he is putting in the last small weight, raise your hand and press the *lower* side of the beam; your scale-pan will instantly fall. The person attending you will begin at once to put in more weights, fancying he has made some mistake. Whilst he is doing this, quickly raise your hand to the *top* of the beam, at a little distance from where the scale-pan hangs. By so doing, the scale in which you are standing will at once rise from the floor, as if too many weights had already been placed against you. The pan in which you stand can thus be easily raised and lowered, and you may have some little amusement.

When but a boy we discovered this trick, and highly enjoyed the confusion of a very decent, but hot-tempered person, who was weighing us. The only reward we got for our ingenuity was a stroke from a rope's end. We will just explain the science of the affair to you. By pressing the underneath part of the beam *upwards*, you lengthen the distance between yourself and the fulcrum of the scales, whilst the other side of the beam remains unaltered; hence you naturally have the effect of casting your side down: whereas, when you *press* or *pull down* the beam on your side, you have the effect of shortening it; hence the side where the weights are held falls down. The whole question rests on the equal or unequal distance between the ends of the lever, or beam of the scale, and its centre or fulcrum.

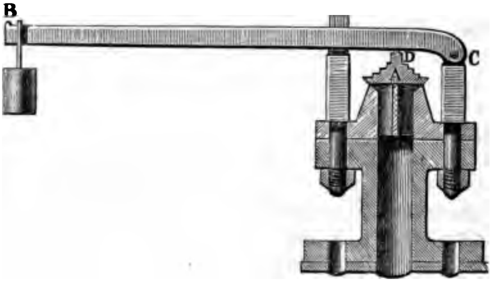
The steelyard, often used by butchers, and at turnpike gates, is constructed on similar principles to those we have just named. At one end is hung the substance to be weighed, near the fulcrum; on the other arm of the lever a small weight rests on notches, and the further this small weight is from the fulcrum the more it can counterbalance a weight on the other side of the fulcrum.

The next kind of lever to which we shall invite your attention is one wherein the fulcrum is at its end, the resistance in or near the middle, and the power applied at the other end; and the best known instance of a lever of this kind is the common hand truck, used in warehouses, for the purpose of removing bales, &c. In it the wheels are the fulcrum, the resistance is the load, and the power is applied at the handles.

You have a very familiar instance in the nut-crackers, in which the nut is placed not far from the fulcrum, that is, the pin which keeps the two arms together; the power, of course, is applied at the further end of the handles.

The third order of lever has an illustration in the safety-valve of the steam-boiler. In this the fulcrum is at the end, the power is applied near it, and the resistance is afforded at that part of the lever most distant from the fulcrum. Our next engraving represents the kind of safety-valve usually employed.

Fig. 1.



A is the valve.
B, the resistance, or weight.
C, the fulcrum.
D, the point where the power is applied, which in this case is the force of the escaping steam.

It will be no part of our plan to enter into a lengthened explanation of the mode of constructing the various machines *in daily* use, which are more or less dependent on the use of levers of either of the three classes we have just described. They are, indeed, so numerous as to defy the possibility of enumeration.

We shall mention a few, which, coming as they do under your daily observation, may acquire an interest from your being enabled to apply a little scientific knowledge when studying their use and construction.

The handle of a common pump is a lever, where the fulcrum is the pin, on which the handle works. That portion of the lever held in the hand is the point where the power is applied; and the part connected with the rod of the pump, that which affords the resistance.

A wheelbarrow is another instance of a lever, and is of the same class as the hand-truck, to which we have already referred.

A wheel and its axle form a continuous lever; for, supposing a rope was passed round the axle, and another one round the wheel, you would be enabled to exert a force similar and applied in a like manner to that we described at page 319, in which case the *centre* of the axle would be the fulcrum.

The capstan of a ship acts on the lever principle, and the longer the handles by which it is worked the greater is the power which results from its use.

In making our roads, the principle of the inclined plane is largely made use of. It has the effect of reducing, or perhaps of making equal, the power required to raise a weight to a higher from a lower level. The inclined plane has numerous applications. In our railways it is termed a gradient, from the Latin word "gradus," a step; and, indeed, an inclined plane is simply a gradual step, instead of a sudden rise, between bodies of two different heights. Contrivances of this kind are much used in the warehouses of London; and thus trucks and barrows may be gradually raised, in a manner which would be impossible if the ordinary stair was employed.

The common wedge acts on a principle similar to that of the inclined plane, and is largely employed for various purposes. In stone quarries it is employed for the purpose of splitting masses of stone. A block of stone is chipped all round, so as to leave a kind of crevice, in which iron wedges can be introduced. The miners then drive the wedges further in, by striking their wide ends powerfully with heavy hammers. We have often seen four of such wedges separate and raise a mass of stone weighing not less than three or four tons. Ships, when in course of launching, or requiring repairs, are often raised sufficiently by means of a judicious application of wedges.

There are many tools employed by our artisans which at first sight would seem to have no relation to the wedge, but which depend on the same principle. Of these we may mention the saw, the plane, knives, brad-awls, awls, razors, needles, nails, &c.

The screw is another form of the inclined plane, as you will at once see by cutting a long triangle from a piece of paper, and winding it round a pencil. You will observe that a screw is formed; and if you employ stiff paper, and after winding it round a pencil, hold your finger and thumb on the paper screw, turning the pencil at the same time, the pencil will work its way through, just as an ordinary screw would if held in a similar manner.

One of the most interesting applications of the screw is that for propelling steam-vessels. It has numerous advantages, especially for ships of war. We have met with many persons who do not seem able to understand how the screw acts on water in propelling vessels; but it is a very simple affair. Supposing, for instance, that a person is taking a screw out of a piece of wood, by unscrewing it with a screw-driver; the wood is in a fixed position, and as the thread of the screw retreats from the wood, so the screw-driver and the hand holding it are driven away, by the power exerted by the muscles of the arm. In the same way, substituting the sea for the wood, and the vessel and steam-engine for the screw-driver and the power of the muscles of the arm, the propulsion of the vessel is effected similarly.

The screw is largely employed in daily life, and for a great variety of purposes. Among these we may mention the screw-press, printing-press, and coining-press, the common screw, the screw jack, used for raising heavy weights, the gimlet, the cork-screw, and other similar contrivances, by which much labour is saved and force is readily applied.

Having spoken of some of the simplest of mechanical powers, we shall make a few remarks on what is called the centre of gravity of bodies; and, although the subject seems rather difficult at first sight, we think that we can mention some interesting, and even amusing experiments, which will illustrate what we mean.

The simplest definition we can give is to say that that point in a body at which all its forces are exactly balanced is its centre of gravity. An instance of this may be found in the boy's game of see-saw. If at each end of a plank a boy of the same weight is placed, then, supposing the plank to be of the same thickness and breadth throughout its length, the centre of gravity of the plank will be half-way between its two ends; and if suspended at that point, its two ends will completely balance each other. If, however, a heavy boy sits at one end and a light one at the other, the centre of gravity will be nearer the end where the heavy boy sits, and therefore, of course, removed from the centre, and nearer to one end than to the other.

This law of the centre of gravity is constantly acted on and attended to in daily life. In loading a cart or vessel, the heaviest part of the load is always placed in the lower part, so as to make the centre of gravity as low as possible. To the neglect of this, many serious accidents have occurred; ships, for instance, with a heavy load on deck, will almost certainly be lost in a storm, because the deck load raises her centre of gravity too high. As we have already mentioned, the use of ballast is to steady the vessel by keeping her centre of gravity as low as possible. Accidents often occur on our rivers through persons in a boat suddenly rising when they are alarmed. By so doing, they raise the centre of gravity from the centre of the boat, and thus almost surely cause their own destruction.

Acrobats preserve their centre of gravity, so as to prevent their falling, by means of a long stick. By balancing this in their hands, they can shift the centre of gravity continually. Great attention is paid to this principle in constructing locomotive engines; for if their centre of gravity is very high, there is always a great risk they may run off the rail. The following experiments will illustrate our meaning.

EXPERIMENT 14.—*To balance an Egg on its End.*—This you cannot do so long as the yolk of the egg remains in its centre; but by shaking the egg violently the yolk will be separated, and by falling to one end will enable you to balance the egg thereon.

EXPERIMENT 15.—Fit an upright wire a foot long into a bung about four inches in diameter, and float this in a pail of water. Now slip on the wire a small leaden ball, which can be raised and lowered. As long as the ball rests on the surface of the cork, the latter will float in a level manner on the surface of the water; but if the ball is raised up the wire, the centre of gravity of the arrangement is raised at the same time, and eventually the whole will fall over to one side. This experiment illustrates the remarks we made respecting the danger of rising in a boat, when on the water.

In our experiments in Natural Magic, we shall introduce some amusing illustrations of the principles we have here laid down, and shall farther mention instances wherein the regulation of the centre of gravity is an occurrence of daily life.

In walking you continually change the position of the centre of gravity by removing the *base* or feet on which the body stands. Although this is so easily and imperceptibly done, we depend on the action of a part of the brain for its continuous exercise. Thus a dead body cannot stand upright; and for similar reasons, a drunken person cannot maintain an upright position. In carrying a load under the arm, the body is inclined towards the other side. In ascending a stair, the body is bent forwards; in descending, we incline backwards. In turning a corner rapidly, or as we observe the riders on horseback in a circus, the body is bent. In each of these cases the alteration of position is taken so as to maintain the centre of gravity, and to prevent the person falling to the ground.

We might add considerably to the remarks we have made in reference to mechanics and allied subjects. We, however, shall refrain from further dealing with the subject, because, although it is one of the deepest interest to the philosopher and practical mechanician, we can scarcely hope to make it of general interest to our young readers. You will observe that we have confined our illustrations to matters which you must necessarily often meet with, and so far as we have gone, we have not forgotten the simplicity of the plan with which we at first set out.

Our young friends will feel interested in the engraving at the head of this section. It represents the engine used by Henry Bell, in January, 1812, for the purpose of propelling a vessel called the "Comet," on the Clyde, and which was the first application of steam to navigation that had been made in Europe. The engine, now in the possession of Mr. Pollock, of Cathcart, near Glasgow, was deposited in the Polytechnic of that city, and fortunately escaped injury during the fire which destroyed the premises of the institution in 1857.

NATURAL MAGIC.

Natural Magic is a term given to amusing instances of applications of scientific laws, and is always an attractive subject to young people. In our former sections we have endeavoured, in as plain a manner as possible, to bring before you some of the most interesting facts connected with experimental science; and although we have omitted many subjects to which we might have referred, we hope to have succeeded in proving to you that the study of science may be made both amusing and instructive.

We now propose to lay aside all reference to laws, rules, &c., and to devote ourselves entirely to your amusement. We shall introduce a variety of curious applications of the different subjects which we have spoken of in the previous pages, but shall leave your own ingenuity to detect the relations between what we have dealt with and what we shall now introduce.

By the word "magic" we generally understand something which is strange and unexpected—something, in fact, which strikes our imagination rather than our reason; and yet, after all, what is more magical or wonderful than those changes which science brings before us? In our Chemical section you will have observed, that by simple means some extraordinary effects may be produced, and which we could never have anticipated. Who, for instance, would expect that the chemist could produce fire from water, a liquid which we generally employ to extinguish flame? Yet this is only one out of thousands of similar results obtained by the application of scientific laws.

In the following pages we shall introduce many amusing scientific experiments, which we have not yet adduced, and shall also put you in possession of several amusing tricks played by conjurors on their audiences; so that when you next attend the performance of a "Wizard," you may be able to explain many of the deceptions of the senses which they practise.

We may here tell you that a great part of the success which attends a public performance arises from the fact that every person present expects, and therefore makes up his mind, to be astonished. While you have your attention fixed on some object to which the performer refers, he is engaged in some other matter which he is about to bring before you. In fact, he endeavours to mistify your reason, while he deceives your senses. Presence of mind, ready wit, and abundant resources, are essential elements of success to conjurors, and some possess these requisites to so great an extent as to deceive the most wary. We fancy ourselves to be tolerably sharp, but even in scientific tricks we have been so well deceived by one or two performers as to have had our conceit completely taken out of us, and we have been compelled to confess ourselves as completely "taken in."

Some years ago we witnessed the performance of some genuine "Celestials." You are perhaps aware that the Chinese excel all other conjurors in the skill and neatness of their tricks. We shall introduce several of these, which they were kind enough to explain to us; and so give you an opportunity of repeating them for the amusement of yourself and friends. We shall follow no arrangement of any sort, leaving you to select such of the experiments as may best please your fancy.

1. *To put a Pound's-worth of Silver into a Wine-glassful of Water.*—Fill nearly to the edge a wine-glass with water. Owing to the attraction which the liquid has for the glass, you may put in nearly twenty shillings'-worth of silver, providing you add each coin gently, and that without causing any of the water to run over.

2. *To break a Stick resting on Two Wine-glasses.*—Place a

lath so that each of its ends shall rest on the top of a wine-glass. Now strike its centre sharply with a poker. The stick will at once be broken, and yet the glasses will be uninjured.

3. *Emptying a Glass of Water without touching it.*—Make a small syphon (see page 306), and having filled both legs with water, introduce the short one into the glass of water; the whole of the liquid will soon flow out.

4. *To make a Prawn empty a Wine-glass.*—Dip a prawn, or large shrimp, into a glass of water, and let its head rest outside of the vessel, placing the middle of its body on the rim of the glass. In a short time the water will be withdrawn.

5. *Another Way of emptying a Vessel of Water.*—Wet a strip of calico, or cotton-wick, and place either in the water, so as to have a long strip hanging outside. The calico will soon empty the glass by its capillary attraction.

6. *To light a Candle without Fire.*—Put a small piece of phosphorus inside the wick, and rub your penknife against a board until it is hot. Then touch the phosphorus with it, which will at once catch fire, and so light the candle. The usual way of doing this is to have a piece of glass-rod, one of whose ends has been heated. We, however, have always succeeded by the plan above named, and it has the advantage of requiring no assistant. We have seen a "Professor" take the *wrong* end of his magic glass wand, and, burning his fingers, he spoiled his experiment at the same time.

7. *Another Way of lighting a Candle.*—Put a little chlorate of potass and sugar (see page 28) into the wick, and have close to you a glass containing strong sulphuric acid. Dip a glass rod in this, and touch the chlorate of potass with it. In trying this, take care that the acid does not spurt into the eye.

8. *To light a Fire with a cold Liquid.*—Pour on the paper of a ready-laid fire a little sulphide of carbon, in which some phosphorus has been dissolved. In a minute or two the paper will ignite, and the fire will rapidly burn up (see page 39). This is a very effective trick, especially if played on persons entirely ignorant of chemistry, as the following anecdote will prove. Whilst preparing our apparatus for a lecture in the vestry of a church in the west of Scotland, a Highland woman was engaged in laying a fire. When she had finished, she found that she had no matches. We at once proposed to set fire to the wood with some "cold water," and very much vexed the good woman when we proposed such a "daft thing." Taking, however, our sulphide of carbon, &c. bottle, and pronouncing some Greek words, we poured its contents on the wood. To the unutterable surprise of the woman, the fire was instantly

kindled. She ran out of the room into the minister's house, declaring that the "deil had got into the kirk," and vowed that she would never enter it again. We learned that she kept her word for nearly two years, and to this day lives under the impression that we hold dealings with the Powers of Darkness.

9. *To blow Fire from the Mouth.*—Have on the table before you some fine paper shavings, and also a small piece of German tinder, wrapped in a piece of paper, and ignited. Put a few shavings into the mouth, and place the tinder dexterously in their centre. After a few moments blow gently through the tinder, and smoke will appear to proceed from your mouth. If you gradually increase the amount of air sent through the tinder, it will at last burst into flame, and set fire to the shavings, especially if you use a common fusee, and light first the end which has no phosphorus. This is a very telling trick, if you proceed carefully in exhibiting it.

10. *Fire produced from the Floor of a Room.*—Presuming that you are amusing yourself in a room without a carpet, you can try the following :—Take equal parts of powdered chlorate of potass and sulphur, and mix them together, by means of a knife. Do not attempt to do this in a mortar, lest they may explode, and injure you. Throw a little of this powder on the floor of the room. Any person rubbing the feet on the ground where any of this powder may be, will cause it to explode with a loud report. An eminent public speaker and author kindly offered to give a reading from some of our novelists, and followed us at the lecture-table of an institute some years ago. Our assistant had carelessly dropped a little of the above-named powder on the floor, with some small pieces of phosphorus. Our friend, in the course of his reading, was illustrating the case of a traveller too late for the coach, and did so by placing his hands on the table, rubbing his feet rapidly on the ground. The phosphorus, &c., soon caught fire, and each time he raised a foot small pieces flew off his boot, producing showers of sparks. The speaker was entirely ignorant of the "brilliant effects" he was producing behind him, whilst the audience in front cheered him most vociferously, fancying that it was part of the performance. We alone were in the secret, and must confess that we never expect to enjoy again so hearty a laugh as we did that evening.

11. *To make Crackers.*—Put about as much of the powder named in the last experiment as will cover the end of a knife, into a piece of paper, and fold it up. Strike it then smartly, by means of a hammer, and it will at once explode with a loud report.

12. *To produce a "Fog."*—Mix together some powdered coal and chlorate of potass, and put the powder into a paper cartridge, made by rolling stiff brown paper round the end of a ruler, fastening one end by means of a little clay, and nearly closing the other by some string. Set fire to the mixture, and hold it under the surface of some water in a basin, on the table. An immense amount of vapour will be produced, which, rising through the water, will fall over the sides of the basin, and produce a very pretty effect.

13. *To set fire to Sugar.*—Mix together some coarsely-powdered lump sugar and chlorate of potass, and place it in a plate. Ask your friends to taste it, and they will at once pronounce it as only sugar, because the salt dissolves but slowly in the mouth. Have ready a glass tube, with a drop of sulphuric acid at its end, which you may call your magic wand. Touch the mixture with this, and it will at once burst into flame.

14. *Port and Sherry Wine out of the same Bottle.*—Take off the end of a common wine bottle, by putting a red-hot ring to the bottom, and then dipping it in cold water. Or you may have it cut off by any glass-worker. Now divide the inside of the bottle into two parts, by means of a sheet of gutta-percha, which must extend from the neck to the bottom, so as to leave no communication between the two sides. You should also close the ends of these divisions before replacing the bottom of the bottle, which can easily be fixed on by means of some shellac dissolved in spirits of wine. The two holes at the neck of the bottle should be made as small as possible. You must now have two holes pierced through the glass, one on each side of the gutta-percha division, say an inch apart, and near the upper portion of the wide part of the bottle. Fill the divisions with port and sherry, and place a finger on each of the side holes. You will find, on trying to pour out the wine, that none will escape, until you raise one of your fingers. You can, by raising the finger which covers the hole of that compartment containing the wine a friend may choose, at once pour out a glass, without the other coming out at the same time. A glass-blower will easily make you one of these bottles, with any number of divisions you please. Of course, each must have a hole, and a finger must be kept pressed on every one, except that from which you wish to pour. Use small liquor-glasses, and you may thus supply a large party, and make them believe that the bottle is inexhaustible. Fig. 1 will give you a good idea

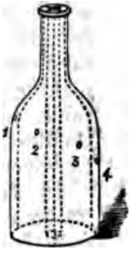


Fig. 1.

of the mode of making one of these bottles. The one represented has four divisions and as many holes, which are indicated by the figures 1, 2, 3, 4.

15. *To draw any quantity of Paper-Shavings from the Mouth.*—Cut a few sheets of fine tissue-paper, of two different colours, into strips, half of an inch wide, and paste them end to end, until you have made two very long ribbons. Roll each of these on a blanket pin, so as to form a cylinder, half an inch thick, taking care to leave out a small end of the paper from the inside of each. Place one of these on each side of the mouth, between the upper teeth and the cheek. You should pretend to draw them out of the throat, and dexterously catch hold of the little piece running out of the centre of each. Draw these from the mouth, and you may then continue to do so until you have covered a table with the shavings. This is a puzzling trick to the uninitiated, and, with a little care, may be made to afford great delight to young folks. We have overheard very venerable persons discussing the "science" of the trick, who little imagined its simplicity.

16. *To make a Candlestick from Paper.*—This is done much after the same way as the last. Wrap round a piece of composite candle a few yards of stiff cartridge paper, an inch wide, first fastening the candle and paper next to it by a piece of string. When the roller is complete, tie the outside also, to prevent it unrolling. Place the roll on a table, and, taking hold of the wick of the candle, draw it upwards, until you have formed a tall pyramid. You can then light the candle, and, if the paper is stiff enough, you may easily carry this paper candlestick about the room.

17. Many amusing tricks may be made by thus economizing space. For instance, have a number of tin cans made which fit in each other, the outer one being a little smaller than a man's hat. Place these on a chair or stool underneath the table from which you are exhibiting your tricks. Having borrowed a friend's hat, show the company that it is quite empty, but take care to drop it, "accidentally," behind the table, and while picking it up put the cans into it. Having placed it on the table, commence removing the tin cans, of course taking the smallest one out first. You may astonish your young friends by covering a large table with saucepans obtained from the hat.

18. Instead of the cans, tie some feathers into a small parcel. These occupy very little space when compressed, but expand very much on being opened out. Flowers, toys, and sweetmeats, with a variety of other matters, may be thus concealed, and afterwards spread among the company.

19. *Floating Soap-bubbles.*—Fill a glass basin, or a fish-bowl, with carbonic acid gas, by using the apparatus described in Experiment 42, page 24. Blow a soap-bubble, and let it fall on to the surface of the gas in the glass vessel. It will present a very singular appearance, and will rest on the surface of the gas, swimming about with every breath of air.

20. *To make an Egg float on a Liquid.*—Make a strong brine, by dissolving salt in cold water, and half fill a glass jar with it. Drop a piece of paper on the surface of the brine, and pour gently some cold water on to it, so as to fill the jar. The object of the paper is to prevent the water and brine mixing. Now drop an egg into the liquid. It will sink in the water and swim on the brine.

21. *The Magic Cash-box.*—Place an electro-magnet, such as we described at page 150, on a stand, with its two poles standing upwards. Over these throw a piece of red baize, so as to keep them out of sight, and bring the two wires from the magnet to any place where you can touch them without being noticed. Hold the wires from a galvanic battery in your hands, so as to be able at any moment to bring them in contact with those of the magnet. Having placed a common cash-box on the baize, and resting on the poles, ask any one present to lift it up, which of course they will easily do. Let them replace it, and again request them to remove it; but this time connect your battery wires with those of the electro-magnet. It will now be impossible to raise the box, owing to the attractive power of the magnet. On disconnecting the latter with the battery, the attraction will cease, and the box will be set at liberty.

22. *A Child may hold a Man.*—Cover the ends of a roller of wood with two brass tubes, and to each of these solder a wire, long enough to reach to your table. The wires should be kept from touching each other, either by gutta-percha or by being covered with silk or cotton. Being thus protected, they may be twisted together, so as to give them the appearance of a cord. Take care that the two brass cylinders do not touch each other. Attach one of the wires to the coil-machine, and bring a wire from the other pole of this machine, close to that which is attached to the other cylinder of brass on the stick, so that you can connect them together instantly. Ask any of the company to take hold of the brass handles; and so long as you do not complete the connexion with the machine they will feel no effect. Make the connexion, when the person holding the handles will receive a powerful shock, and will be unable to let go until you disconnect the wires. A child may hold the wires, and bring

them in contact without receiving the slightest shock. For a description of the coil-machine see page 152.

23. *Spirit-rapping.*—A table may be constructed, which by means of electro-magnetism will serve for the purpose of not only illustrating "spirit-rapping," but which, if cleverly managed, may afford a vast deal of amusement. To arrange one, attach wires to each of two legs of a table in a distant part of the room, and bring them under the carpet, so as to be out of sight, to the table at which you are standing,—on which have a small galvanic battery ready. The wires are intended to convey the electricity of the battery to a small electro-magnet (see page 150). The magnet must be fixed underneath the top of the distant table, so as just to leave room for a small keeper above it, which will become the "rapper." This keeper is simply a piece of soft iron attached to a steel spring, which is used for the purpose of maintaining the keeper close to, but not touching, the table. The poles of the electro-magnet are to be placed facing this keeper; and the wires from your table attached to each of its wires. On sending a current of electricity from your battery, the keeper will be drawn to the magnet; and on stopping the current the keeper will fly back, and strike the table, making one rap. As often as you make and break the contact, at the same moment the keeper will rap, even if your table is many feet from it. Your friends not acquainted with science will look under the table, expecting to find some one concealed, but, of course, with no success; and if you cleverly hide the wires, they will be completely at a loss to discover the means you employ.

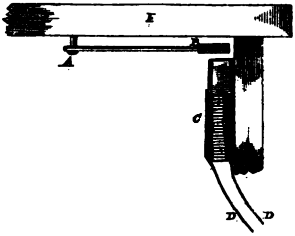
This plan is the one adopted by the conjurors in their spirit-rapping illustrations; and that you may more distinctly understand our description, we add a section of the arrangement, referring you to our section on Electro-Magnetism for a full account of how to construct the electro-magnet. The whole arrangement will not cost above four or five shillings. (See fig. 2.)

To employ this, some of the company must suggest a question, and your signal for an affirmative answer should be two raps; for a negative, three; and for "not understand," give one rap. A very ingenious arrangement was adopted by Mr. Anderson, the Wizard of the North. His table ran on brass rails, and up each leg was a wire attached to the magnet. Of course the rails served as conductors, and he could push the table away from him to any distance, and so make the deception more complete.

24. *Magic Hat-boxes.*—By means of three hat-boxes and some carbonic acid, you may puzzle both old and young folks. Hang a hat-box at each end of a scale-beam, and balance them

carefully. Have by you another hat-box filled with carbonic acid, and pour its contents into one of the hat-boxes suspended from the beam. This will immediately fall, owing to the weight of the gas introduced. Your friends will not see anything pass, and of course, if ignorant of chemistry, will be much astonished at the result.

Fig. 2.



A is a nut by which the spring of the keeper, or rapper, is fastened to the table.
B is the keeper.
C, the electro-magnet.
D D, the wires reaching to the battery.
E, the table top.

25. *Another Mode of trying the above.*—Fix one of the boxes with its open end downwards, and having filled another box with hydrogen, of course with its mouth also downwards, insert this under the box on the beam, and let the hydrogen enter. The box will at once make the beam rise, owing to the gas passing into it being so light. If you now turn this, so that its mouth shall be upwards for a few moments, the hydrogen will escape and the boxes will be again balanced. (See page 22, Experiment 38.)

26. Instead of the latter plan, hold an india-rubber tube, reaching from a gas jet, under the inverted box. As the gas enters the box will rise.

27. *To put out a Row of Candles without touching them.*—Place two or more lighted candles in front of you on the table, and carefully pour some carbonic acid gas on each. They will at once be extinguished, and apparently by nothing, for, of course, the gas is invisible. (See Experiment 44, page 25.)

28. *To relight an almost extinguished Fire.*—Powder some nitre, and if a few red sparks are left amongst the cinders, throw some of the nitre upon them; they will instantly re-

kindle, a rapid combustion will take place, and in a few minutes you will have an excellent fire produced.

29. *To hang a Ring by a burnt Thread.*—Soak some sewing cotton in a strong solution of alum or common salt, and when dry attach a light ring to it. You may then set fire to the thread, but the ring will still hang, owing to the salt forming a thread in place of the cotton one, by being fused together by the heat.

30. *To make Plaster Busts luminous in the Dark.*—Leave the bust for some time before a fire, until it is quite warm, and then rub it over with a solution of phosphorus in olive oil. This is made by putting some of that substance into a bottle containing a little hot oil. The bust, if taken into a dark room, will present a beautiful appearance, and will be a source of great amusement to young folks.

31. *To silver a Penny Piece.*—Put a three-penny piece into a little mercury, in which it will soon disappear. Spread a little of the amalgam over the penny, and when well covered, place the penny on the bars of the grate in which a fire is burning. The quicksilver will fly off, leaving the real silver on the surface of the penny. Any copper object may thus be plated.

32. *To hang Two Forks on the Point of a Needle.*—Fix two forks on opposite sides of a wine-cork, so that they shall hang downwards in a slanting position. In the bottom of the cork fix a needle with its point outwards. Fix a needle with the eye upwards in the cork of a wine-bottle. By dexterously placing the point of the needle from the cork holding the forks on the head of that in the wine-bottle, you may balance the forks, and make them turn round rapidly. Our engraving will explain this fully to you. (See fig. 3.)

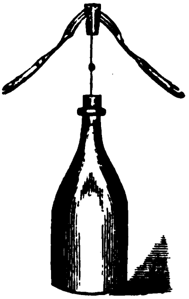


Fig. 3.

This will require a little patience on your part; but if two or three persons are trying this at the same time, it generally produces plenty of fun by the numerous failures each make.

33. *Writing by Magic.*—Soak a few pieces of paper in a solution of prussiate of potass, and dry them. They will appear white by candle-light. To know them again put a pencil-mark on each. Now mix them with sheets of common writing-paper. Your ink should be made by dissolving two or three crystals of green copperas in water, and will appear like common water, then add to it three or four drops of nitric acid.

On handing the paper to a friend, take care that he selects a sheet of common paper, and ask him to write with a quill pen, using the solution just named, and he will produce no effect. Now use, yourself, the same ink, but employ one of the prepared sheets. Your writing will appear of a beautiful blue colour.

34. *Magic Plates.*—Wet three plates with a solution of copperas, and let them dry. Now make, in three different bottles, a solution of nitrate of baryta, prussiate of potass, and sulphocyanide of potassium (see page 54, Experiment 147), and take care that they are all clear and colourless. They will then seem like water, but if you pour a little of the contents of each on to each plate, the first will seem to produce *milk*, the second blue *ink*, and the third *blood!*

35. *The "British Wine" Manufacture.*—Fill a basin or glass tumbler with cold water, and add a few drops of the sulphocyanide solution. It will still appear like cold water. If, however, you have previously wetted two of your fingers with a solution of green copperas, you may ask each member of the company to change the water into port or sherry, when, of course, they will not succeed; but on your stirring the water with your "copperas-ed" finger, it will instantly change to a splendid red colour, and may be either "port or sherry" according to the length of time you stir it up.

36. *Magic Boxes.*—By means of a simple contrivance, you may produce a vast amount of amusement in a large party. For this purpose have a square box made, open at its two ends, and into each end have a drawer, which must slide into each other, but the inner one must be a little shorter than the one fitting next the case. They will appear as in fig. 4, where A, B, represent the two drawers; C the space between their ends; and D, the outside case containing the two. Place in the drawer, B, anything you please, say a guinea pig, a rabbit, or pigeon, and place the case on the table. Now ask any of the company to

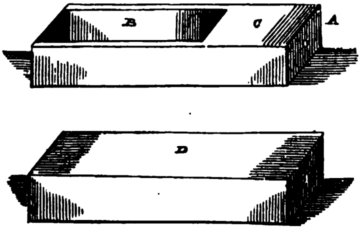


Fig. 4.

favour you with their handkerchiefs, which place in the hole, C, having first shown them that A is empty, by drawing it out half way. Close the box, and take the first opportunity of turning it round unperceived, so that box B may stand on the table in the same position that A had done previously. If you now draw out B, of course the animal may be removed, and you can at once prove the power of the magician, by showing the transmutation of silk into an animal. To make this trick more complete, you should have previously borrowed a hat, and placed it on the table. As you remove the box knock down the hat by "accident," and quickly remove the handkerchief from the box into it as you pick it up. You can then show that by "some means," the handkerchief had travelled, but, of course, need not explain *how* it was done. The conjurors generally send the handkerchiefs behind the scenes, where a person irons and scents them, and they are returned to the audience out of a plum pudding, or something else, in the course of the evening.

37. Nearly all the transmutations of the "Wizard" are carried on by similar means. They have tin cases, of various shapes, fitting inside each other, by and in which they conceal the various articles they borrow. A vast deal is done by "confederacy;" that is, they have several persons in the audience who, although apparently strangers, have duplicates of the articles destroyed. They must, however, be very careful not to take anything from the wrong person; that is, a stranger, as we shall show you in the next trick.

38. *The Magical Cash-box, or Money made to Fly.*—Have fitted into a common cash-box, two false divisions, a quarter of an inch from each end, one of which may be a fixture, and the other movable on an hinge, to which a spring is attached, ending in a nut outside.

To make the construction of this more evident, we annex an engraving, with a description, from which any intelligent tinsmith will be able to carry out the plan.

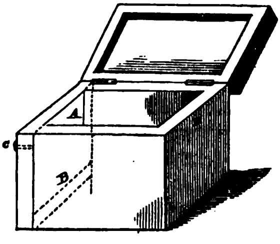


Fig. 5.

In fig. 5, A represents the movable lid, B its hinge, and C the nut, which, by means of a spring, will let A fall down, when needful; D is the other division, which is only added to make the box look uniform. Of course, the ordinary small box usual in cash boxes must not be placed inside.

Before using the above, place four half-crowns in the false division, A, and take care that the lid shuts so tight as to prevent them rattling against the side of the box. Now place the box open on the table, to show that there is nothing inside; you should also shake it, for the same purpose. You now lock the box, give the key to any one present, and hang the box at some distance from you. Borrow four half-crowns from the company, and place them in a tea-cup on the table; shake them repeatedly to show that they are in it, and then dexterously remove them into your pocket. After making any number of remarks on the power of the wizard, until the company are pleased or tired, announce that the effect you desire is produced, and strike the nut, C, of the cash-box. The lid, A, will instantly fall, the half-crowns will drop into the box, and you may then rattle them, ask for the key, unlock the box, and hand what the company consider to be their own money back again.

This is an excellent trick, if well managed; but we must tell you of a better one, which we played on a person who thought himself too clever to be ever matched.

Having watched him place four genuine half-crowns in the cash-box before the exhibition, we placed four persons amongst the audience whom we had supplied with tin medals. On our wizard asking for four half-crowns, these men instantly pressed forward, and one very "kindly" acted as collector, handing him the money. (?) After the process we have described had been gone through, the men received back, not their medals, but, of course, the genuine half-crowns, which had been placed in the box long previously. After the exhibition had concluded, we visited our friend behind the scenes, and most heartily enjoyed the joke of seeing him draw from his pocket four pieces of pewter, instead of the genuine coin of the realm. We let him wax warm for some time, and after he had confessed himself as completely done for once in his life, his money was returned to him, on condition of his paying a fee for being well conjured. Mind that you are never served in the same way.

39. *The Magic Tea or Coffee-pot.*—Get the tinsmith to make you a tea-pot in two divisions, so that one side shall be completely separate from the other, but each having a small pipe running into the spout. At the back of each, near the handle,

have two small holes bored, and the lid should fit on very tight. Fig. 6 will represent one, where A A are the two divisions, B B the separate spouts, hid in the main one, and

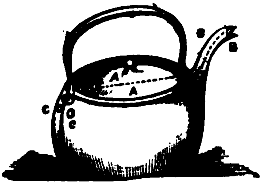


Fig. 6.

C C two small holes at the back and near the top of the pot. Fill one part with milk and the other with tea or coffee, and fit the lid on tightly. Now place a finger on each hole, and try to pour out the liquids. You will not succeed, because no air can get in to take the place of the liquid; but, by removing either finger, the liquid of that division will at once run out, and thus you can supply tea and milk out of the same pot.

If you put tea on one side and coffee on the other, you can pour out either, after ascertaining your friend's choice. Another division and another hole will enable you to pour out milk, tea, and coffee from the same vessel. We need scarcely remind you that the arrangement is very similar to the bottle we described in No. 14.

40. "*Milk*" *made from Water.*—Fill a tumbler with a solution of nitrate of barytes (poison), and put one drop of sulphuric acid at the end of a teaspoon. On stirring up the liquid with the spoon it will appear just like milk.

41. *Music by Magic.*—Have the arrangement described at page 248, fig. 4, laid on one side, so that the stick shall be in a horizontal, instead of a vertical position; and to keep the musical box in close contact with the stick, fix the two together, by means of a wire. On placing this on the table before you, none of the company will hear any sound; but if you place at the further end of the stick a small thin wooden box, the sound will at once become evident. The company will naturally suppose that the sound proceeds from the little box placed on the stick, and will be puzzled on finding the box empty.

42. *Hearing by the Teeth.*—Invite them to close their ears by their fingers, and to bite the stick with their teeth; the sound will at once be heard, or rather felt.

43. *To turn a Glassful of Water over the Head without spilling the Liquid.*—Enclose a tumbler in a strong net, attached to which should be four strings, say two feet long. Fill the tumbler with water, and swing it to and fro by the string, each time extending the distance, until it acquires sufficient velocity to allow you to raise it to a nearly horizontal position. You may now carry it beyond this, and swing it round in a circle for any length of time, without spilling its contents. Bring it to rest in a gradual manner.

44. *To turn a Glass of Water upside down without spilling it.*—Fill a wine-glass with water, and place on the top a large card. Hold the card on the edges of the glass with the left hand, and turn the glass upside down with the right hand.

45. *Invisible Writing.*—On a square of window-glass write any sentence, by rubbing strongly with a piece of pointed glass rod, just in the same way as you would write on paper. Of course, the writing will be invisible. Now, mix a little tartaric acid and carbonate of potash in a glass of water, and pour the solution immediately on the glass plate. In a few minutes all your writing will become visible by small crystals of cream of tartar being formed at the edges of the marks you had previously made on the plate.

46. *Another Way of producing the same Effect.*—Write on a piece of paper with a quill pen, which has been greased with a little lard. If carefully done, the writing will be invisible. If, however, you now dust some powder, or dust of any sort, over it—using, for instance, the pepper box,—your writing will at once appear, owing to the dust settling on those parts where the grease is. It has been suggested that similar means were employed by the priests at the Greek and Roman temples. Supposing, for instance, that a sentence had been written on the entrails of one of the slaughtered animals, by means of a little fat; it would be invisible until the skin was dipped in dust, when, of course, the writing would at once appear.

47. *To make a Watch-glass revolve rapidly on a Waiter.*—Hold a waiter or tea-tray in a slanting position, and at the upper end place a watch-glass. Of course, the glass will slide rapidly to the bottom. But, now put a drop of water at the upper part of the tray and place the watch-glass in it. Instead of sliding down as before, in a straight line, it will spin round on its axis with great rapidity during its descent.

48. *Optical Puzzle.*—On a round card, say twelve inches in diameter, have painted on one side the picture of a mouse, and on the other that of a cage. Through the sides of the card

pass a string, which is used for the purpose of making the card spin round rapidly by holding the two ends of the string between the finger and thumb of each hand. On twisting this rapidly round, the mouse will seem to run in and out of his cage for reasons explained at page 189, Experiment 4. This instrument is called a "Thaumatrope," and fig. 7 will illustrate its construction.

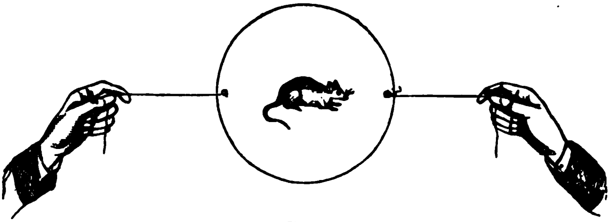


Fig. 7.

49. *To make an Egg stand on its End.*—Either remove the contents, by making a small hole through one end, or, retaining these, shake up the egg for some time and pour in a little mercury, which, falling towards the lower part, will make the egg to rest on that end in an upright position.

50. *To make Figures with round Ends stand in an upright Position.*—Fix the figure of a man to a ball in which you have poured some melted lead. Or the whole figure may be made of plaster, with a lump of lead at the lower part. In whatever direction you bend this figure, it will regain its upright position. These are generally made of the shape illustrated in fig. 8, where the shaded part shows the position of the lead.

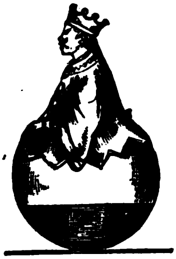


Fig. 8.

51. *To make a Ball play in the Air over a Jet of Water.*—Use the fountain described under the section Pneumatics, page

266, or any fine jet of water will do. On the water, at a short distance from the jet, place a wooden ball, about an inch in diameter. As long as the water plays with any force, the ball will rest in the air, supported by the water. A bent pipe attached to the tap of a cistern, and ending in an upright jet, will answer the purpose very well instead of the fountain.

52. *Figures produced by Sound.*—Procure a thin sheep's bladder, and having moistened it with water, stretch it evenly over the top of a glass tumbler (such as we mentioned at page 242, under the head of Sound). Allow this to become quite dry, and it will form a kind of drum-head over the glass. Strew some fine sand over it, and play a violin near it, or place it on the top of a piano at which a person is playing. The vibration will affect the sand, and beautiful figures of various forms will be produced amongst it.

53. *Coloured Wafers; a curious Optical Effect.*—Place three wafers, one each of red, yellow, and blue, on a piece of white paper, and look steadily at them for some time. On removing the eye towards the white part of the paper the wafers will appear to be present, but will have changed to each other's colour. Thus, the red will appear green, the yellow blue, and the blue of an orange tint.

54. *Another Optical Effect.*—Paint a plaster bust of a bright-red colour, by means of vermilion or red lead, and fix the eyes intently on it for some time. On removing them, and looking at any other object, or, even if you shut your eyes, the "spectre" of the bust will appear, and be of a green colour.

55. *To make an Artificial Rainbow.*—Cast the rays of light passing from a prism (see page 192, Experiment 7) on to some steam rising from boiling water, or on smoke produced from smouldering brown paper. The appearance is very beautiful, and presents the full effect of the rainbow.

56. *To make an Æolian Harp.*—Obtain a thin wooden case of an oblong shape, and having only two sides, and from either end stretch lengthwise strings and wires, such as are employed by musicians, fastening them at either end by means of nails. If the wires are tightly stretched and the arrangement is placed in an open window, so that the air may pass through on entering the room, a beautiful soft humming sound is produced as the draught of air causes the strings to vibrate.

57. *Magic Glass Drops.*—These can be purchased at most of the instrument-makers, or you may obtain them at a glass-house, by having some melted glass cast in small quantities of the size of a cherry into cold water. You may strike one of these by a hammer without breaking it, but on taking off the sharp end, or

rubbing one against some sand, the whole will fall into a fine powder.

58. *Trees growing in the Parlour.*—Suspend a chesnut or acorn inside a clean pickle or preserve-bottle by means of cotton threads, and then fill the bottle with river water, until the liquid just touches the seed. The bottle should then be placed in a warm situation, such as the mantel-piece of a room in which a fire is burning. You may thus, during winter time, have the pleasing result of an oak or chesnut growing. We have seen some of these produce several leaves in the course of a few weeks. You can afterwards remove it to a garden-pot.

59. *Plants growing on a Bottle.*—Wrap a wine-bottle tightly with flannel and dip it into water. When well wetted press on the surface of the flannel a quantity of mustard and cress seed, which will soon adhere. If you take care to keep the flannel continually moist, the seeds will soon take root, and in the course of a fortnight's time you may gather a crop of salad from the outside of the bottle.

60. *Brown Paper Alive!*—Dry a piece of brown paper carefully before the fire, and hang it, by means of a silk thread, at a distance from any surrounding body. Now ask any of the company to make the paper come to him on presenting his hand, and he will most probably not succeed. Strike it yourself three or four times with a dry silk handkerchief, and then bring your hand near to it. The paper will at once move towards you, owing to your having excited electricity on its surface by the friction of the handkerchief. To make the experiment successful you must take great care to have the silk thread, paper, and handkerchief perfectly dry.

61. *To make a Live Fish jump off a Plate.*—Place a live flounder on a sheet of zinc in a plate, and touch his back with a piece of copper or silver whilst the latter is touching the zinc. The electricity produced will generally cause the fish to take a flying leap.

62. *To produce a Flash of Light by two Metals.*—Place a half-crown as high up the cheek as possible, and placing a piece of zinc on the tongue, let the two metals touch. The moment you do so a bright flash of light will be perceived across the eye near which the metals are placed. If you use a piece of platina, the effect will be more evident.

63. *The Magic Watch.*—You may have much fun in a large company by proposing to stop any watch without opening the case, and after stopping it to set it on again at your pleasure. To do this, wear gloves on both hands, so as not to excite suspicion, and place inside one glove a small horse-shoe magnet. On

taking a watch into the hand holding the magnet, the steel balance will cease working, owing to the attractive power of the magnet; but on removing it to the other hand, the wheel will immediately recommence working.

64. "*Animal Magnetism.*"—By suspending any object in which a magnet has been enclosed, by means of a thread, and holding another magnet in your hand, as in our last experiment, you can draw to, or drive away, the article from your hand, according as you present the different poles of a magnet to each other. We have sometimes puzzled our friends by enclosing a magnet in a stuffed bird which was suspended by a thread between two parlours. By first calling the bird in the usual manner, you add to the success of your device.

65. *Curious Experiment with Flame.*—On a roller of wood, say twelve inches long, fix a piece of brass pipe six inches long, so that one half of the length shall be brass and the other wood. Round each of these tie a sheet of writing paper, and hold each end successively in a candle or gas-flame. The paper covering the wood will at once catch fire, but that surrounding the brass will remain uninjured, or at all events will be but slightly charred.

66. *To boil a Wine-glass of Water in a Sheet of Writing-paper.*—Force a sheet of writing-paper into the hollow of the hand, so as to form a kind of basin two or three inches deep, and collecting the edges of the paper together, fold them over each other so as to form a rim. Into the paper vessel thus formed pour a glass of water, and hold it over a candle-flame. The water may thus be boiled with ease, without burning the paper.

67. *The Magic Cave.*—Construct a representation of a cave by means of pasteboard, painting the outside so as to resemble a natural one, and take care to have the outside edge two inches high, and that the bottom is air-tight. At any place out of sight inside put a small saucer or plate, to which add some chalk and a little vinegar or muriatic acid. You may light a number of tapers in any part inside, which, if placed above the level of the edge of the cave, will burn very well, but on dipping another taper into the lower part it will be at once extinguished, by the carbonic acid gas given off. In Italy there is a natural cave into which dogs are thrown for the amusement of visitors. The instant they arrive inside the cave they fall down, apparently dead, but on being removed into the open air they speedily recover.

68. *Mechanical Paradox.*—*To make a Ball ascend whilst it is falling!*—Place two bagatelle sticks with their points

together, and the thick ends slightly separated. If an ivory ball is now placed at their thin ends, and gently touched, it will travel apparently upward until it arrives at the thick end of the cues.

69. *Flame on Water.*—Place a piece of camphor in a basin of water, and set fire to it. You will find that it burns with a white flame, and that it will travel about in the water in a very curious manner.

70. *Singular Effect produced by a Light passing through Water.*—Fill a tall confectioner's glass, or a glass fish-bowl, with cold water, and place behind it a candle, so that the flame shall be at about half-way up the vessel. On looking through the liquid, the light will be only seen through it in straight lines. Now pour into the water a solution of twenty grains of quinine and a drachm of dilute sulphuric acid, stirring it up with the water at the same time. On again looking through the water sideways, you will find a peculiar and beautiful blue colour is afforded, and that the light seems diffused throughout the liquid. The effect will be greatly increased by trying this in a dark room, and by so shading the candle that its rays shall only pass through the glass. This may easily be done by putting a cylinder of zinc round the candle, and cutting a small slit opposite to the side of the glass through which only the light is to pass.

71. *Singular Mechanical Effect.*—Hang a brass ring or light wooden hoop to two pieces of string, and twist these together as far as possible. On letting them loose, the hoop or ring will spin round; but instead of continuing in a perpendicular position, it will gradually rise to a horizontal one, so that the side opposite to that where the string is attached will eventually become level therewith. This is a simple illustration of the principles on which "gyroscopes" are constructed.

72. *The Sound of a Church Bell obtained from a Poker.*—Hang a poker by a piece of string, and hold this between the teeth. Let a friend strike the poker whilst you keep your ears closed by your fingers. A deep musical sound will be produced resembling that of a church bell.

73. *An Electric Shock produced from a Gong.*—Hold a large gong, by means of a stout string passed twice or thrice over the left hand, and strike the gong smartly by a drumstick. You will occasionally receive a very similar effect on the wrist of the hand holding the gong to that produced by a shock from an electric coil-machine. We have never heard the effect mentioned before, and only accidentally discovered it some years ago, whilst striking a very large gong. It requires,

however, that you should hold the instrument in a peculiar way, which you must arrive at after several trials, although you may by chance hit upon it on the first attempt.

74. *Moirée Métallique.*—Pour on a sheet of tin-plate a little dilute muriatic acid, and you will soon observe a number of crystalline forms produced on the surface. When these are fully developed, wash the plate in abundance of cold water, so as to remove any trace of acid. The plate may then be varnished over with some copal varnish. By using coloured varnish the effect is greatly increased, and the plate assumes a very pretty appearance.

75. *Nobili's Rings.*—These are most beautiful rings, formed on a piece of steel by means of a small galvanic battery. To produce them, place a piece of polished steel in a plate containing a solution of sugar of lead, and attach the steel plate to the wire coming from the *platina* end of three cells of Grove's battery. Hold the wire from the zinc end in the solution, within an eighth of an inch over the centre of the steel plate. Beautiful rings of the oxide of lead will be at once produced, and in a few seconds the steel should be removed and carefully washed in distilled water. This is one of the prettiest effects produced by a galvanic battery, and the colours obtained are similar to those observed on mother-of-pearl. Take care to make no mistake with reference to the wires, in placing them in the solution, as the process is the *reverse* of electrotyping.

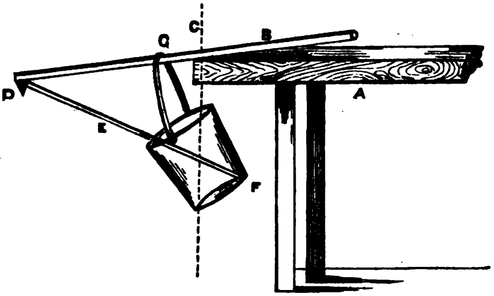
76. *To make Money fly.*—Most of our young friends can succeed in this feat by the time the holidays are finished, but few, perhaps, are able to make money fly and afterwards to return. We shall therefore endeavour to teach them this important lesson. Tie a piece of string firmly round a lucifer match, or piece of wood of similar shape, and nail the two ends of the string into a piece of wood, so that the match or stick may lay lengthways between them. If you now raise the match, so that it may lay on the opposite side of the nails, the string will become twisted, and will draw the match back again. To prevent this, let the end of the stick farthest from the string rest on a piece of cobbler's wax, which will retain it for some time. Place a shilling on that end, and when the wax ceases to hold, the stick will spring back to its old position, and project the coin to a considerable distance. By placing a similar arrangement under a wooden figure of a frog, &c., such may be made to spring to a considerable distance, much to the amusement of the young folks.

77. *Curious Experiment with Carbonic Acid.*—Fill a tall glass jar with carbonic acid gas, by throwing into it some chalk and

muriatic acid—a little of each will be sufficient; or you can fill it as described at page 24 in our Chemical section. Into the jar so filled introduce a syphon, till filled with the gas. Now draw off the gas from the tall jar into a tumbler, just as you would use the syphon for drawing water (see page 306). If you place a lighted taper in the tumbler, it will be extinguished as soon as the gas reaches it, and any person ignorant of science will be at a loss to account for such a result.

78. *To make a Stick, without any Support, hold a Pail or Weight hanging from it.*—Place a broom-stick on a table, so that half of its length may extend beyond the edge of the table, and at the underneath part of the stick cut a small notch. Hang a pail or weight in a notch in that part of the stick which is near to the edge of the table, and fit another stick into the notch, so as to force the pail beneath the table. The pail may now be filled with water, and although it apparently has no visible means of support, it will hang from the stick without any danger of falling; because its centre of gravity is behind the point where it is supported. The illustration below will point out the manner in which this singular experiment may be carried out. (See fig. 9.)

Fig. 9.



A is the table; B, the long stick; D, a notch at its end; E, the short stick, one end of which rests in the pail at F; G, the handle of the pail. C shows the line behind which the centre of gravity is maintained.

79. *Curious Experiment with Two Gases.*—Half fill an air-jar over the pneumatic trough with oxygen, and then pass in a cork or piece of wood nearly as wide as the jar. You may then fill the remainder of the jar with carbonic acid gas. The object of the cork or wood is to break the force of the latter gas as it passes in, and so to prevent its mixing with the oxygen. Remove

the jar from the trough by means of a plate in the usual manner. If you now take out the cork from the neck of the air-jar, and dip in a lighted taper, the flame will burn brilliantly. Immediately plunge it into the lower part of the jar, where the carbonic acid gas is, and it will be extinguished. Raise it to the oxygen, and it will be re-lit. If you take care to have a long wick, and perform your experiment dexterously, you may extinguish and re-light the taper a number of times in the same jar.

80. *The Salamander, or Fire-eater.*—Some time ago a performer became very famous by walking unhurt into, and remaining some time in, the midst of a large fire. It was stated that he employed powerful chemicals to render his body insensible to heat. We are not aware of the exact process he adopted, but our young friends may try the following feats without danger. For this purpose wash the hand with a little dilute sulphuric acid, which has a tendency to harden the skin and make it a bad conductor of heat. Having thus prepared the fingers, you may take up and hold for a few seconds a red-hot coal. Indeed, after frequently experimenting with acids, the fingers become almost callous to heat. We have repeatedly burned the skin when showing the power of the galvanic battery in melting wires, and have been quite unaware of the fact until we perceived the black mark of the charred skin across the fingers. A red-hot coal, or a piece of burning paper, may be safely held in the mouth, if you hold the head back and gently drive the air out of the lungs at the same time. In this case take care not to drop the burning article down the throat, as that would give a speedy and unpleasant termination to your attempt. The Chinese and Indians are great proficients in the art of "fire-eating." Our young friends will find a full explanation of the means by which red-hot lead may be handled and red-hot iron plates walked over, without injury, in our section on Heat, page 178.

81. *Curious Experiment with Ivory Balls.*—Hang three billiard balls by means of string, so that they may just touch each other, and move one away to some little distance. Now let it drop so as to hit the second one. This will not move, but the third one, receiving the motion of the first, through the middle one, will fly off to a considerable distance. Our young friends will remember that a similar effect is often produced when one marble strikes another at the well-known game of ring-taw.

82. *The Phantasmascope.*—This is a very amusing toy, and is made on the principles mentioned at page 192, under the section of Light. A circular piece of cardboard, twelve inches in diameter, is fixed on a handle by means of a pin at the centre,

on which it can freely turn round. On one side of the circle figures, in different attitudes, are pasted or painted, and over each a small slit is made. On turning the card rapidly round, and looking through the slits, you will perceive on a looking-glass placed in front, the reflection of the figures, which seem to be in rapid motion and all alive. Amongst many of the illustrations used are horses and men leaping gates, acrobats, &c., all of which afford great amusement to young folks. The annexed engraving will illustrate the construction and use of this singular optical toy.

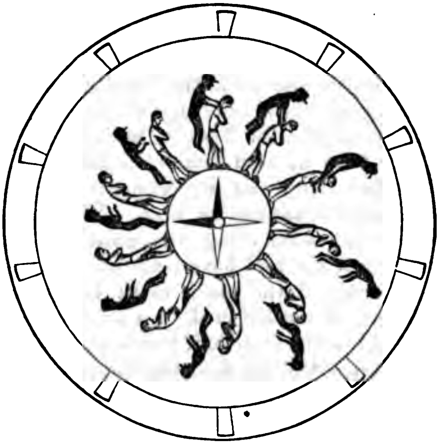


Fig. 10.

83. *To empty a Decanter without "pouring out" its Contents by the Neck.*—Have a very small hole drilled at the bottom of a decanter, and when filling it in the ordinary way place your finger on the hole. If you afterwards replace the stopper, having previously greased it, so that it may fit the neck of the decanter, and be quite air-tight, no liquid will pass out of the small hole, because no air can enter to press the liquid out. You may hand the bottle round to the company, shake up the wine, &c., and they will be at once persuaded that there is no "magic" in it. But have made a tin stand, neatly japanned so as to resemble those usually employed to hold decanters. It must be big enough to hold as much liquid as the decanter contains. In the centre of the stand have a hole drilled, which must be in such a position as to be exactly under the fine hole

of the decanter when the latter is placed on it. A hole should also be made at the side of the tin case at the top, to allow of air passing out, when the wine is descending. After handing the bottle round, ask for a handkerchief; throw this over the decanter, and when placed on the stand, dexterously remove the stopper, by lifting it up, and thus allowing the air to enter. The wine will immediately flow out of the glass vessel into the tin one by means of the small hole. You must, of course, engage the attention of your friends, by relating some extraordinary instances of aërial or any other flights, and having gained time until the whole of the wine has passed out, replace the stopper, remove the handkerchief, and proclaim the bottle empty ! a fact which none of your friends will doubt, and perhaps none will be able to understand.

84. *The Parachute.*—Our young friends may have some amusement in trying the two following experiments with two different forms of the parachute. The simplest illustration of this machine is an umbrella or parasol. If you attach a weight to the handle of one, and drop it with the weight downwards, it will descend very slowly, and well illustrates the action of those parachutes which are sometimes attached to balloons. One which will ascend in the air, on a windy day, may be made by attaching pieces of sewing cotton, six inches long, to the four corners of a sheet of tissue paper, and after tying the threads together, attach a small stone to act as ballast. If you hold one of these open at the corner of a street, the draught will frequently take it to a considerable height, owing to its exposing a considerable surface to the action of the wind.

85. *Incombustible Ladies' Dresses.*—An experiment, both amusing and useful to ladies, may be tried by making a dress of printed calico, one half of which should be soaked in a strong solution of sulphate of ammonia, and dried, the other half being made up without this preparation. On applying a light to such a dress, the unprepared portion will catch fire and burn with much flame ; but the prepared part will not ignite, indeed it will scarcely burn if placed on the top of a fire.

86. *Curious Physical Trick.*—Much amusement may be afforded by inviting a person to pick up a shilling whilst he places both heels against a wall, from which he must not remove them, whilst attempting to reach the coin. Owing to the impossibility of maintaining the centre of gravity, in this position, the person trying this will be sure to fall forward, and of course will fail to reach the coin.

87. *Curious Experiment with Heat.*—Place before you three basins, one containing water mixed with ice, another lukewarm

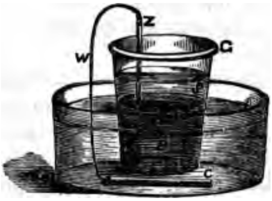
water, and the third water as hot as the hand can bear. If you plunge one hand into each of the cold and hot basins, and then place both hands in the middle one, you will experience a sensation of cold in that removed from the hot basin, and heat in that brought from the cold one.

88. *To produce Minerals by means of Electricity.*—This is a very interesting experiment, because you may, by very simple means, produce exactly the same appearance, &c., in a piece of plaster of Paris; as you will observe on visiting some copper mines. For this purpose, half fill a garden pot, six inches deep, with plaster of Paris, by stirring some of this powder in a basin of water, and pouring the mixture into a porous garden pot, where it must remain until it becomes solid. Now solder a copper wire to a piece of zinc and a piece of copper, so that the two metals may be placed, one in the inside of the pot, and the other so that the pot may rest on it, and cover the intermediate wire with sealing-wax. Fill a basin, say to a depth of four inches, with a strong solution of sulphate of copper, adding to it a little sulphuric acid. In this basin place the piece of copper, and on the metal place the pot. Bend the wire so that the zinc may rest inside the pot, and touching the plaster of Paris; and fill the inside with a solution of common salt. Having done this, throw a cloth over the whole arrangement, and leave it for two or three weeks, replacing the loss of liquid both in the basin and pot, by occasionally adding some water. At the end of the time named, you will find, on breaking the pot and plaster in half, that the copper has crept in and assumed various beautiful forms. In some places you will observe it in crystals; in others as a layer of a rich blue or purple colour; and if you allow the lump to dry, it will form a very pretty ornament for the chimney-piece, being, as we already have stated, a complete counterpart of a natural mineral. We have succeeded with iron and other metals, by using them instead of copper, which, however, we have given as being the easiest to commence with. To assist you in constructing one of these interesting arrangements, we annex an engraving, and a description of the various parts to which we have referred. (See fig. 11.)

89. *Loud Explosion with Coal-Gas and Air.*—Fill a sheep's bladder with air, and having pressed out about two-thirds, fill up the bladder with coal gas, and then tie the neck tightly with a string, so as to prevent the escape of the two gases. As the explosion produced on igniting the mixture is very powerful, the experiment should only be tried in a garden, lest you might injure, and perhaps destroy, various articles indoors by

the violent concussion produced. Having, therefore, taken the bladder into the open air, prick it with a pin, and instantly apply a light. A tremendous report will be given, and the bladder will be torn to pieces.

Fig. 11.



B is the basin holding the copper solution.
C, the plate of copper on which G, the garden-pot, rests.
P, plaster of Paris in the pot.
W, the copper wire covered with sealing-wax.
Z, zinc plate inside the pot, hanging in the solution of salt, S.

90. *To collect an Inflammable Gas from a Pond or Ditch.*—Most of our young friends will have noticed bubbles of gas rising to the surface of a stagnant pond during the heat of summer. This gas burns on the application of flame, and is the cause of that singular appearance called Will o' the Wisp, which often leads the benighted traveller into a pond by its deceptive light. To collect this gas, dip a tumbler into a stagnant sheet of water, and raise it with its mouth downwards, so as to retain the water inside. You must now stir the bottom of the pond with a stick, and the bubbles of gas will rise to the surface. Hold the tumbler over these, and collect as much gas as will fill it. When full, apply a light, and the gas will immediately catch fire. Instead of a tumbler, you may fill a number of bottles with the gas, and, having corked them, may reserve your experiments with the contents till you return home.

91. *Curious Motion of a Metal on a Sheet of Paper.*—Fold a sheet of blotting-paper, and lay it in a plate, moistening it with a little warm water; place on it a small piece of the metal sodium, and in a short time the metal will take fire and run in every direction over the paper, as if seeking for moisture.

92. *To put a Shilling into a Bottle without touching either.*—

On the neck of a bottle wide enough to allow a shilling to drop into it, balance a ring on its edge, and at its upper edge place a shilling; thus the ring will rest in the neck of the bottle, and the coin on the top of the ring. If you suddenly pull the ring away, by means of a thread passed through it, the shilling will drop into the bottle. This is owing to the ring being withdrawn so rapidly as not to allow time for it to communicate motion to the coin.

93. *To obtain Skeleton Leaves.* — This forms a very pleasing amusement for young persons, especially ladies. To obtain what are called anatomized or skeleton leaves, soak leaves of the currant or other shrub in water for some time; the solid part will then gradually rot out, and leave only the fibres. These will be of a brown colour, and must be bleached by means of a weak solution of chloride of lime (bleaching-powder). They must afterwards be carefully washed, so as to free them from the chloride of lime, otherwise they will speedily rot. They should then be dipped into a little gum-water, and dried. By means of some thin wire they can be bound together, and if neatly arranged, they form a beautiful ornament for the drawing-room.

94. *To obtain large and regular Crystals of any Salt.*— Make saturated solutions of each of the following salts, by dissolving in separate vessels as much of the salt in boiling water as the liquid will take up; namely, sulphate of copper, prussiate of potass, and bichromate of potass, each of which can be obtained of any chemist and druggist. Whilst still hot, pour the solution into other glass vessels, and hang in each a crystal of the salt of the same kind, by means of a piece of sewing-cotton. In the course of a week you will thus obtain one very large crystal of each sort, that of the sulphate of copper being blue, of the prussiate of potass yellow, and of the bichromate of potass a dark red. By occasionally adding fresh concentrated solution, you may thus increase your crystals to almost any size. When they have become as large as you desire, remove them from their solutions, and dip them into a little warm water for a few seconds. This will wash off any superfluous solution which, by crystallizing on the large crystals, would spoil the beauty of their form. Alum may be formed into very large and regular crystals, by similar means, and any of the salts we have named will remain beautiful objects if carefully preserved from injury by being covered with glass shades, and thus protected from dust.

95. *Magic by the Magnet.*—Under the head of Magnetism, we have already mentioned what are called magnetic curves.

Much amusement may be afforded to young folks by spreading some fine iron filings on a sheet of paper placed on a thin table. If you now bring a strong horse-shoe magnet underneath the table, so as to be near the iron filings, they will instantly rise on an end, as if alive, and by moving the magnet in various directions the effect may be made highly amusing.

96. *Curious Experiment with Heat.*—A straight bar of different kinds of metals may easily be made to bend by simply heating it. For this purpose have a piece of brass and iron, each an inch wide, one-sixteenth of an inch thick, and two feet long, bound together by means of three screws, and placed at intervals of six inches. Of course the bar must be straight in the first instance, but on being held in the two hands and heated at its centre in a gas-flame, it will bend into a curved form, owing to the brass expanding more than the iron.

97. *Producing Ice by means of the Cryophorus.*—By employing a water hammer, already described, a very singular experiment may be tried. Remove all the water to one end, so as to leave one bulb entirely empty, and to this apply a freezing mixture, or one of pounded ice and cold water. The evaporation which will take place from the water in the other bulb will produce so great a degree of cold as to convert the liquid into a solid mass of ice. The instrument, when thus employed, is called a Cryophorus, or "frost bearer."

98. *To illuminate a Lump of Alum by means of Electricity.*—Bore a hole through a large crystal of alum, and insert at each end a copper wire, whose ends should be brought near to each other, but must not touch. On connecting these wires with the inside and outside of a charged Leyden jar, and thus sending a spark between them, the whole crystal will be most brilliantly illuminated, and will present a beautiful appearance.

99. *Singular Appearance to be obtained from Loaf Sugar.*—Our young friends are generally acquainted with the chief experiments which may be tried with sugar, especially at holiday times. We, however, here present a new one to them. Warm a pestle and mortar until they are quite dry and hot, and put into the mortar two or three lumps of loaf sugar. If you take them into a dark room, and pound the sugar sharply, bright flashes of light will be produced.

100. *Heat produced by a Liquid becoming Solid.*—Make a very strong solution of Glauber's salts, by putting as much of them into boiling water as it will dissolve, and set the solution by in any place where it will not be disturbed. It will retain its liquid state; but if you dip a thermometer into it when

cold, the whole will suddenly become solid, and the mercury in the thermometer will at once rise.

101. *To melt an Inch off a Poker by means of a Common Fire.*—A very common forfeit in some games is that of making a person *bite* an inch off a poker; but an inch may be easily *melted* off. Make the end of the poker red-hot, and then touch it with a roll of sulphur. The iron will melt away just as a tallow candle would do if held in a gas flame.

102. *Light from a Stone.*—Heat gently in an iron spoon a small piece of fluor spar. On removing it into a dark room it will afford a beautiful light, something similar to that given off by phosphorus. This effect has been called fluorescence, and does not require for its production anything like the heat which would make the spar red-hot. You can obtain the mineral of any operative chemist.

103. *To engrave on Eggs.*—Cover an egg with some melted wax, and when cold, trace through the wax any writing you please, so as to leave the shell exposed. Now dip the egg into some strong pickling vinegar, and leave it for about four hours. You can then remove the wax by washing it off by means of spirits of turpentine, when you will find your writing deeply "bit" into the substance of the shell.

104. *Amusing Experiment with Soap Bubbles.*—Blow some common gas from the gas-jet, through a strong solution of yellow soap in a basin of hot water. A large number of bubbles will be formed, and on applying a light, they will catch fire and give a slight explosion.

105. *Flame from Ether.*—This should be tried in the open air, or in a room devoid of furniture. Pour a tablespoonful of ether into a Florence flask, and heat it over a candle. On applying a light to the neck, the vapour of the ether will catch fire, and you may thus obtain a flame several feet long. The flask should be held by means of a piece of brown paper folded round its neck, to prevent the heat injuring the hands.

106. *To make Mosaic Gold.*—Heat together in a crucible or iron ladle, a mixture of six parts of tin, three parts of mercury, three parts of sal-ammoniac, and about the same of flowers of sulphur. Most of these ingredients will be sublimed by the heat, and a solid shining substance of the appearance of gold will be left behind. This is what is called mosaic gold, and is used for the purpose of making inferior kinds of jewellery.

107. *To make White Gunpowder.*—Powder separately a little sugar, prussiate of potash, and chlorate of potash. Mix these powders in the proportion of one part each of the two former *to two* of the chlorate. On being ignited, this mixture will

explode like gunpowder. It has been proposed to use this in place of common powder, than which it has a greater explosive force.

108. *Curious Experiment with Gas.*—Fill a glass jar, held with its mouth downwards, by holding it over a gas-jet. When full of gas, introduce and squeeze in it, one of the squeaking india-rubber doll's heads, sold at toy shops. The sound produced will be much shriller than that afforded in the air, resembling in fact a loud scream.

109. *To set fire to Zinc by means of a Candle-flame.*—Procure at the zinc-plate manufacturers some fine shavings of the metal, such as are produced in making zinc door-plates. If you hold some of these in the flame of a candle, they will catch fire, and burn with a beautiful blue flame, which will surprise those who are unaware that metals can be ignited and burned with ease.

110. *To boil a Can of Water without a Fire.*—Put a tin can, filled with water, into a basin, and surround it on all sides with some fresh quicklime, on which pour some water. Great heat will be given out, and the water in the can will soon boil.

111. *To cool a Liquid, such as Wine, without using Ice.*—Pound up five ounces of Glauber's salts, sulphate of soda, and pour on the powder four ounces of cold dilute sulphuric acid. Any vessel containing a liquid may be speedily cooled by immersing it in this mixture. This is a very simple mode of cooling wine, when no ice can be obtained; we have used it in pic-nic excursions to the gratification of our friends on a hot summer's day.

112. *To dry a Piece of Paper by means of a Liquid.*—Pour a little strong sulphuric acid into a glass-stoppered bottle, and hang a piece of wet paper inside, replacing the stopper. In a short time the acid will absorb all the water from the paper, and thus will render it quite dry. Of course the paper must not be allowed to touch the acid. Leaves of trees, flowers, and other objects, may easily be dried in this way; and for the purpose of keeping such articles, it is much better than that of pressing them between the leaves of books or sheets of blotting-paper, as by this plan the forms of the objects are kept uninjured.

113. *To kill Insects without giving them Pain.*—Many of our young friends are fond of keeping specimens of butterflies and other insects. The old plan was to impale them alive, by means of a pin, which is a very cruel method. The insects may be instantly killed by dropping them into a jar of carbonic acid gas, the preparation of which we described at page 24. By this method the insects at once die, and, generally speaking,

the wings remain extended. Whilst we have the gratification of studying their beautiful forms, we have not to regret that our pleasure has cost them pain, if we adopt this plan.

114. *To preserve Dead Birds and Small Animals.*—Until you are able to have such stuffed, you can prevent them putrifying by dropping into their mouths some creosote, a liquid which you can obtain of any chemist. This plan is extremely useful when some time must elapse between obtaining the object and its being properly prepared. It has the advantage also of not injuring the colour of feathers, &c., which many chemicals, answering the same purpose, would do. We have kept birds, &c., for six weeks thus, without their undergoing any change. We give you the two last recipes, to enable you not only to pursue your amusement in experimental science, but also in natural history, which affords a vast variety of objects of interest to young persons.

115. *A Candle may be sent through a Piece of Wood without being broken.*—Having loaded a pistol with powder, press into it a composite candle, using the candle instead of a bullet. If you now fire off the charge, the candle may easily be driven through a panel, say a quarter of an inch thick, and it will pass through without sustaining the least injury, except perhaps a few scratches on its surface.

116. *Curious Syphon Experiment.*—Fill two wine-glasses with *distilled* water, and into one put a little common salt, and into the other a few grains of nitrate of silver. Place the salt solution on a book, and let the silver one rest on a table. If you connect the two by means of a piece of wetted lamp-cotton, the salt solution will pass over, and, mixing with the silver solution, will produce the chloride of silver. Any person watching this will perceive a solid substance, of a pure white colour, falling from the cotton thread, owing to the production of the salt we have named. Solutions of copperas, and prussiate of potass, corrosive sublimate and iodide of potassium, and various others, may be used, giving various coloured solids.

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